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CONSTRUCTIONAL ENGINEERING

INCLUDING PRESTRESSED CONCRETE

JUNE 1957 **VOL. LII. NO. 6**

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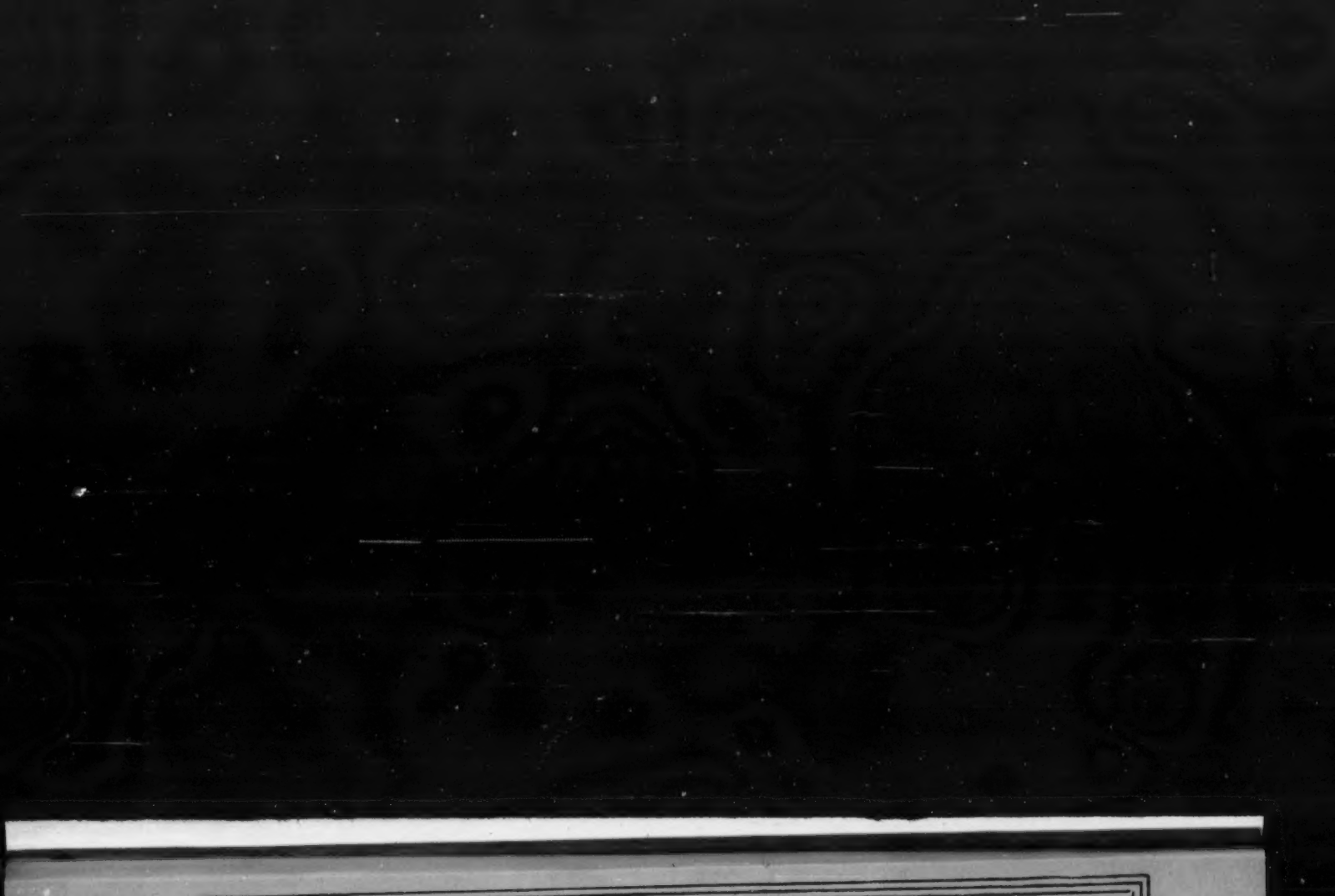

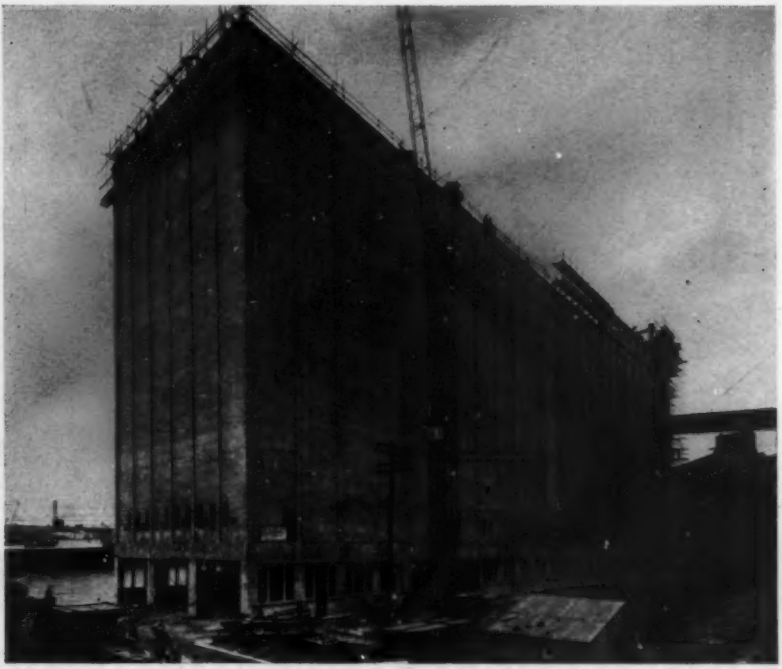

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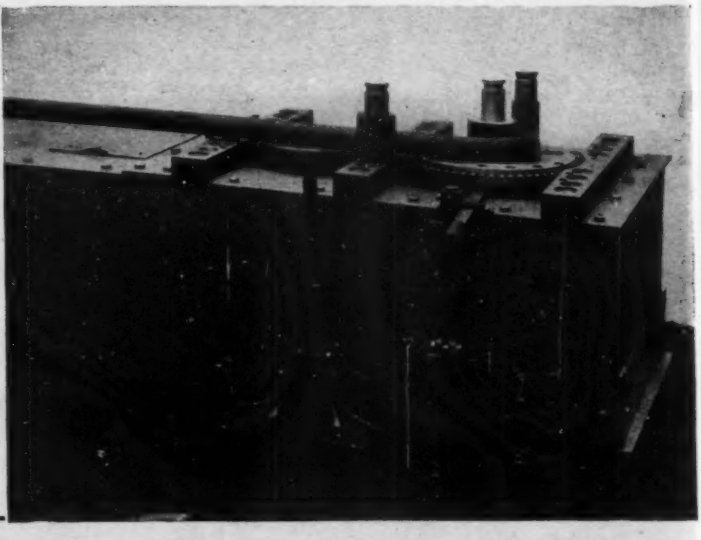

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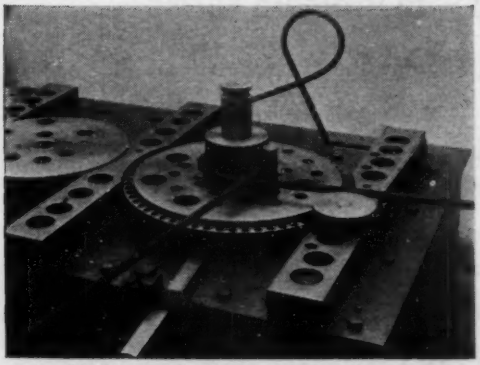

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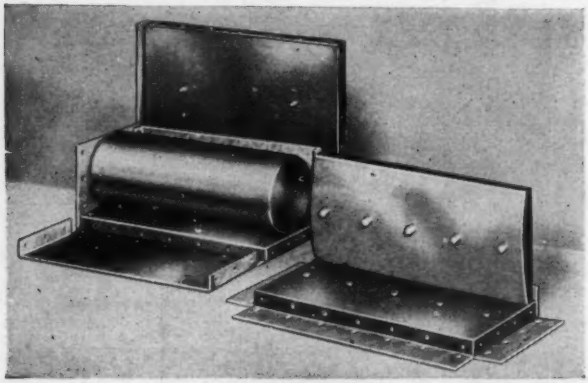
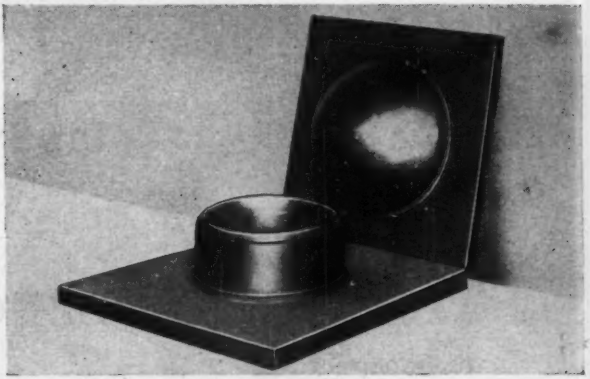
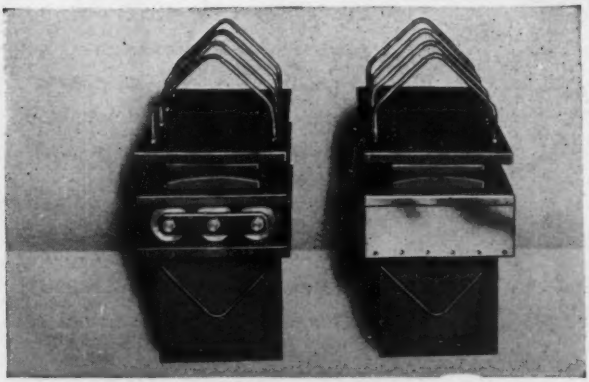


Illustrated are a few examples of various Bridge Bearings recently constructed by Westwoods.





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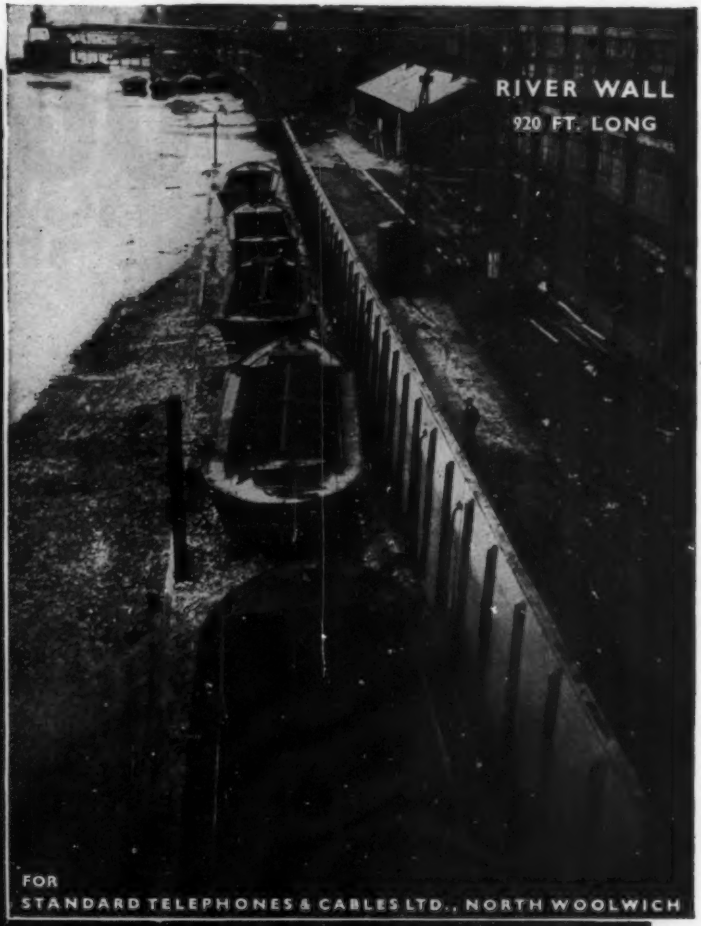

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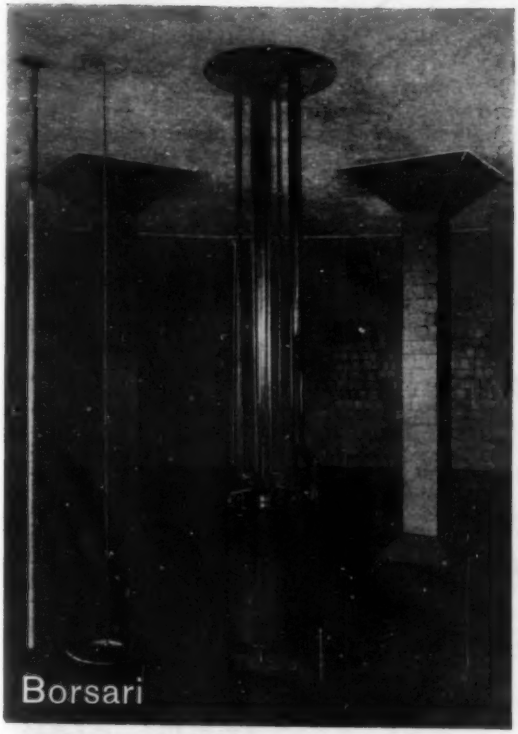

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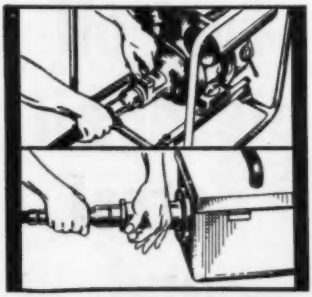

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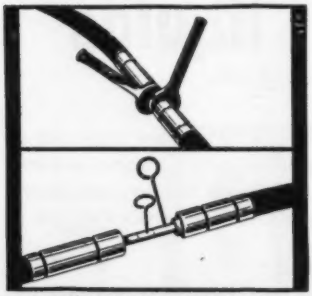

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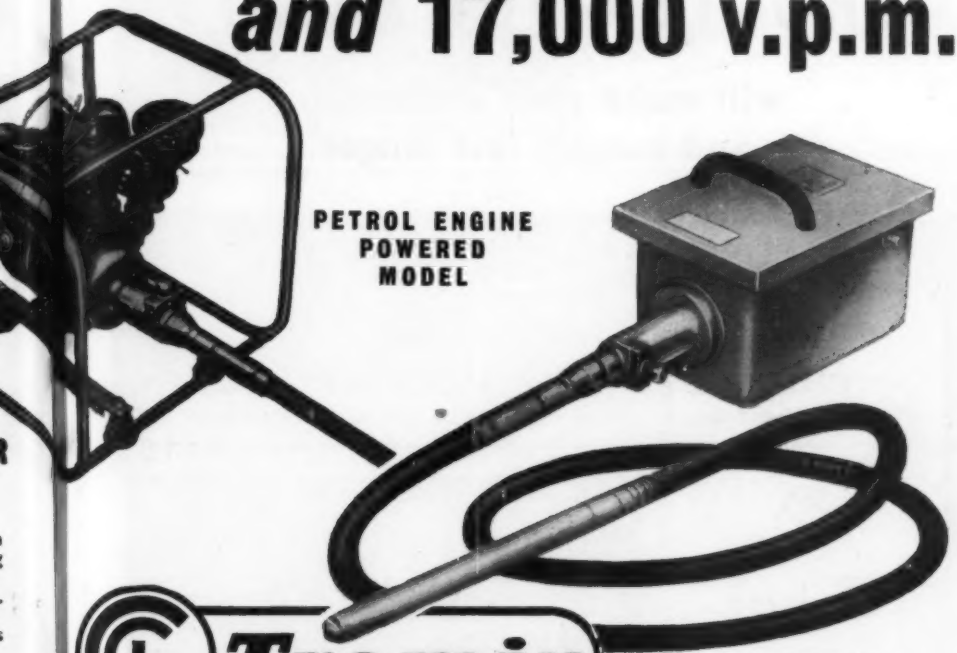

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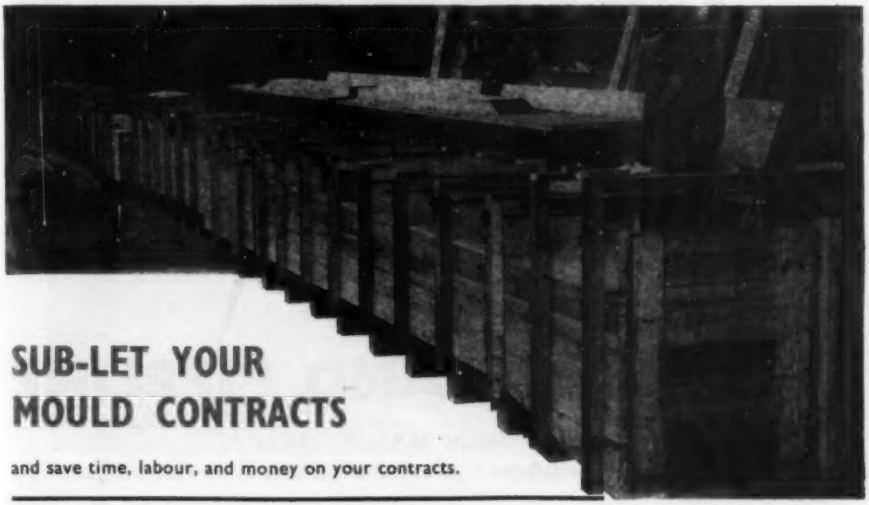

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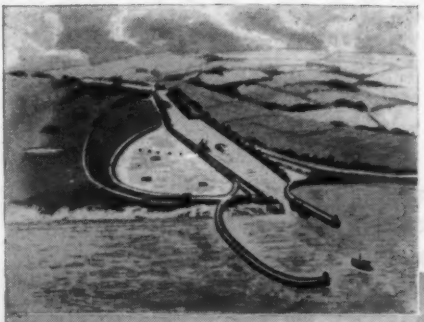

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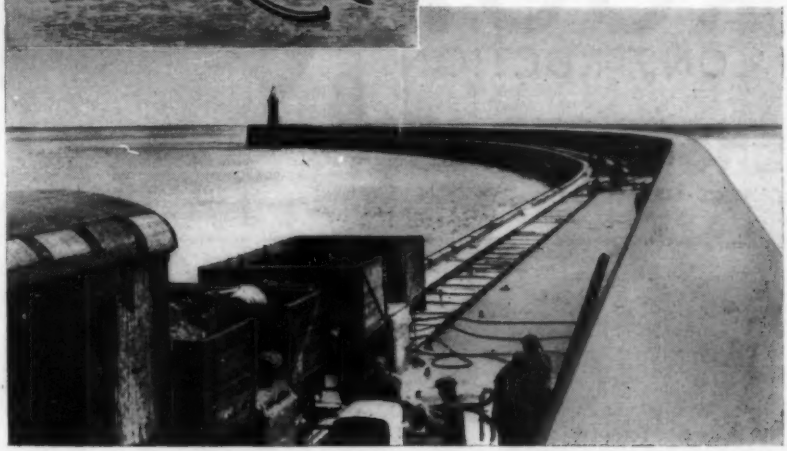

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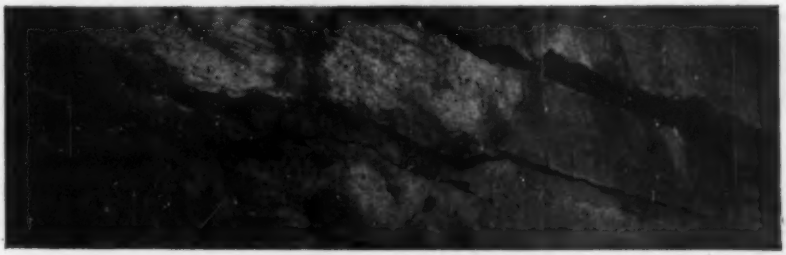

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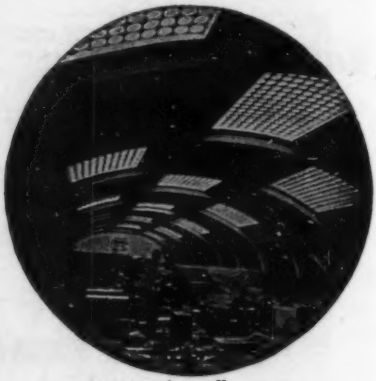

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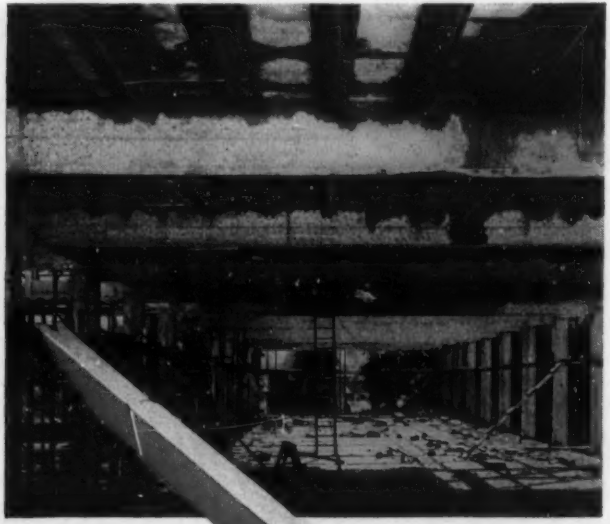

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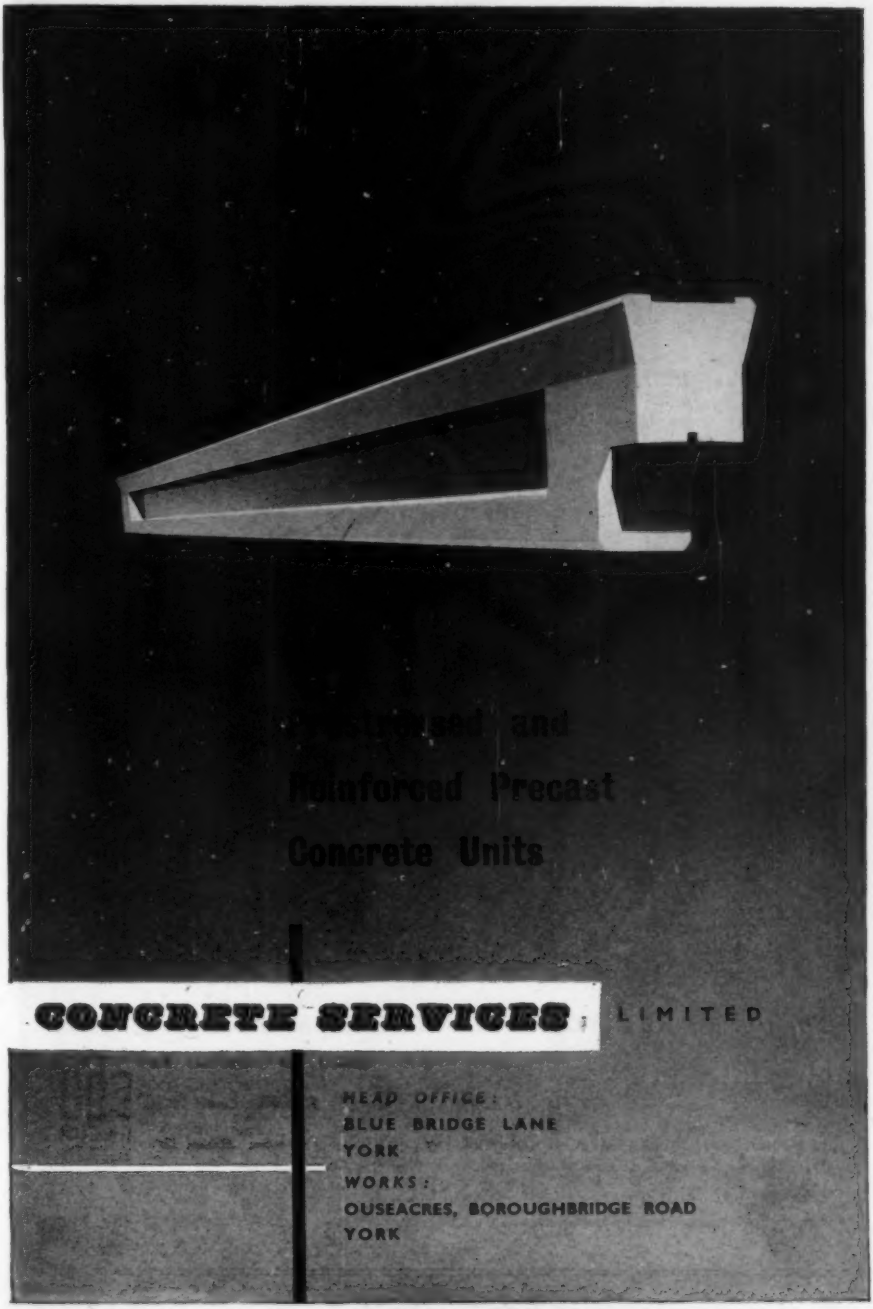
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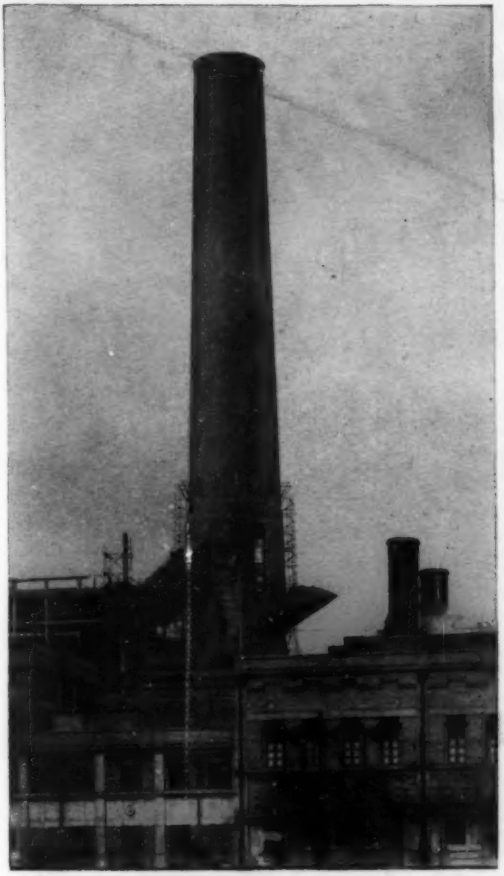

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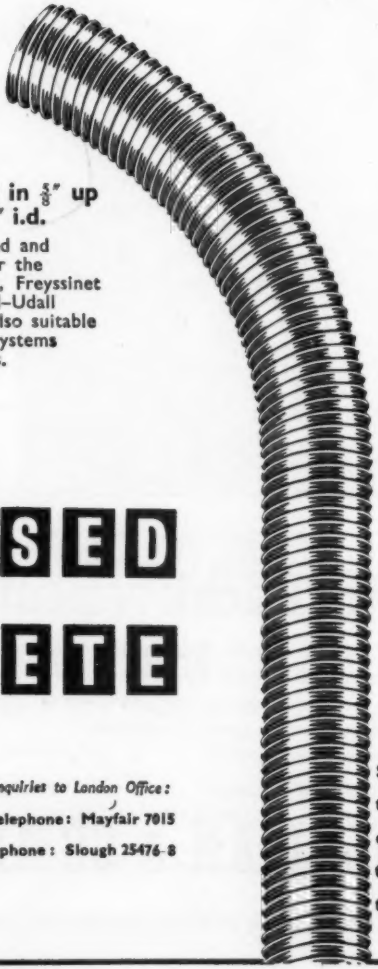

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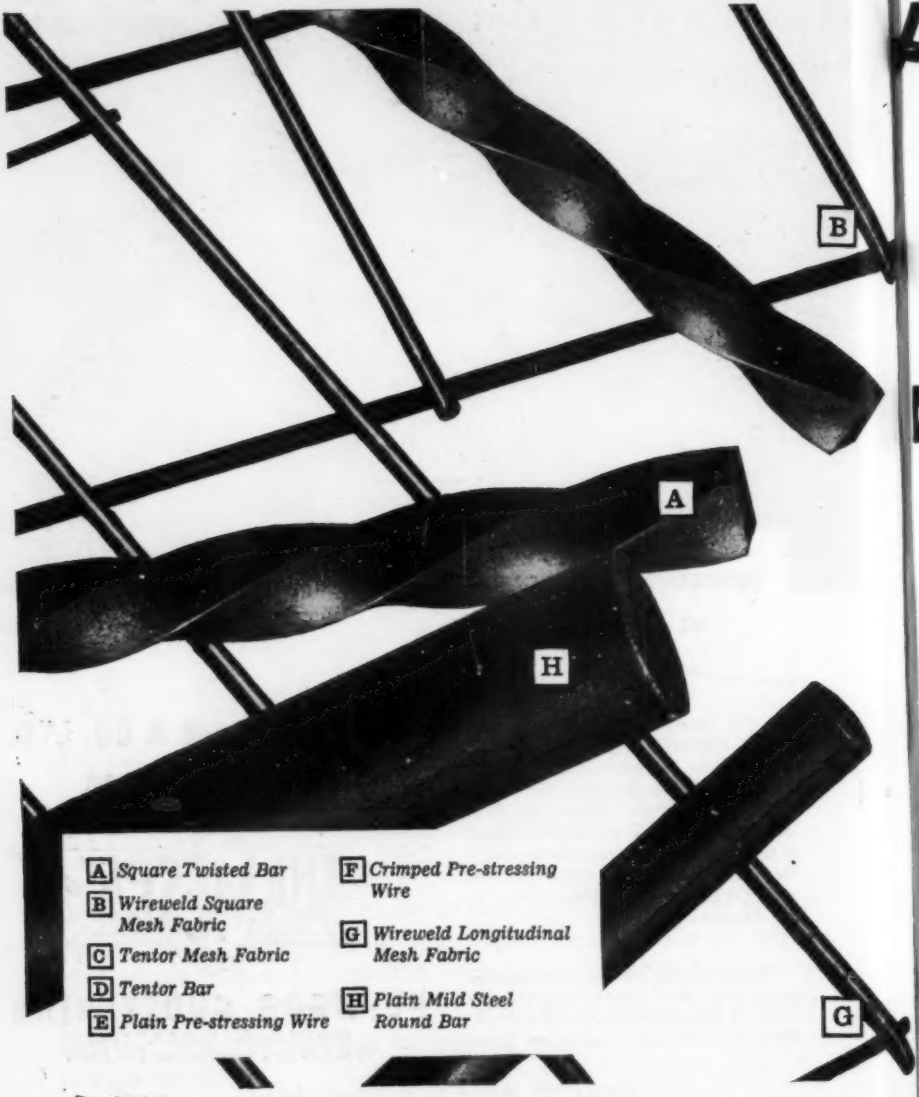

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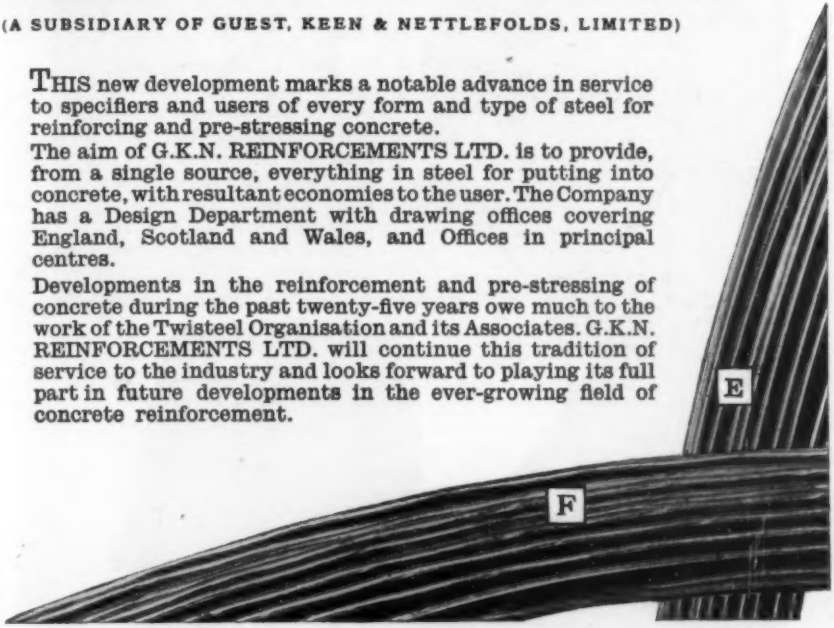

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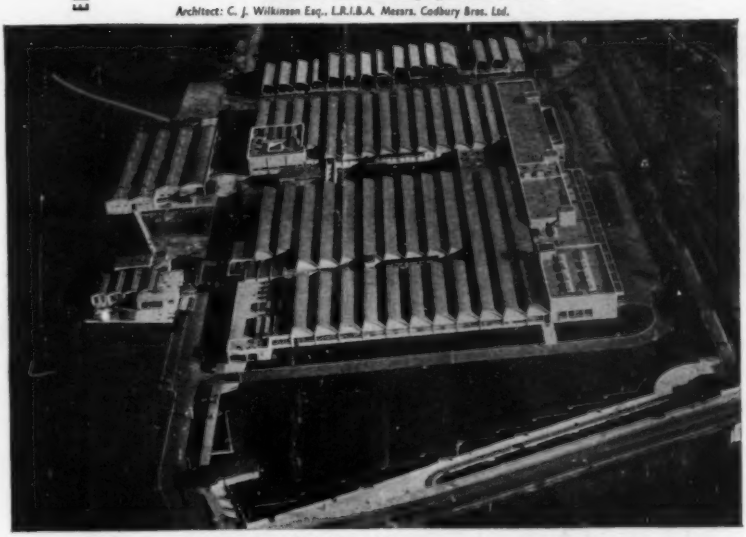

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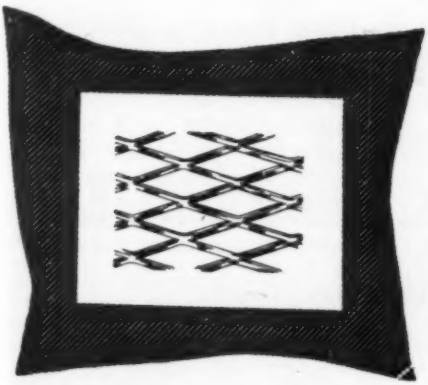

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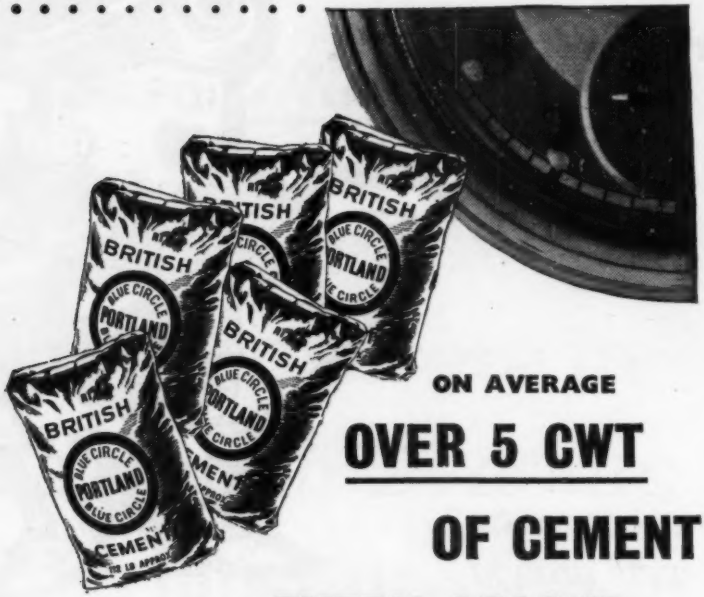

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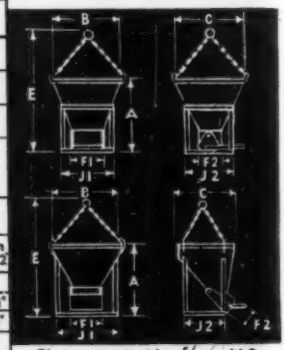

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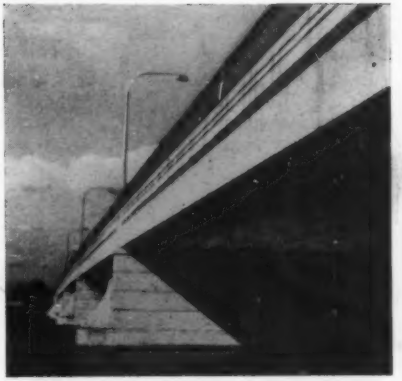

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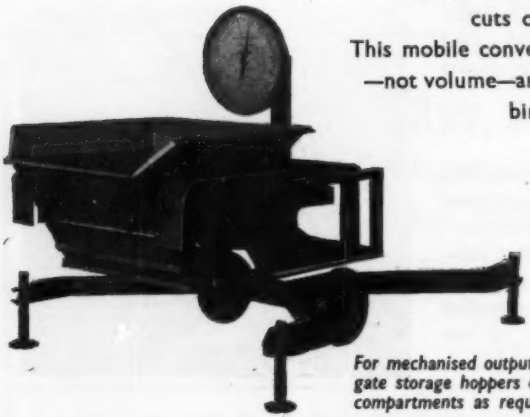

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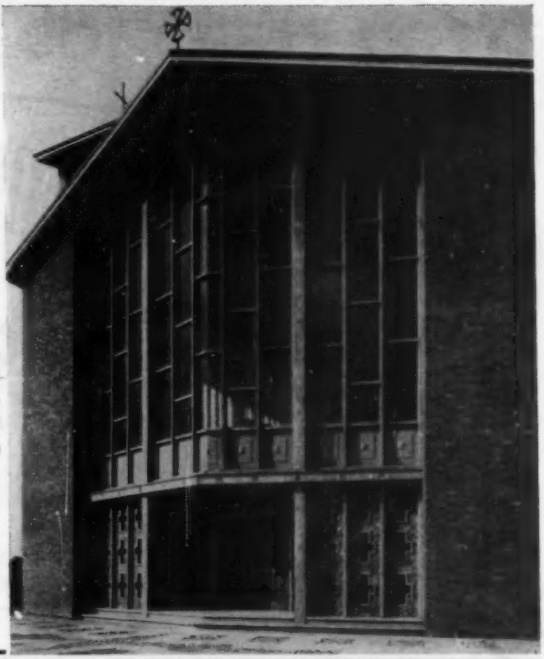

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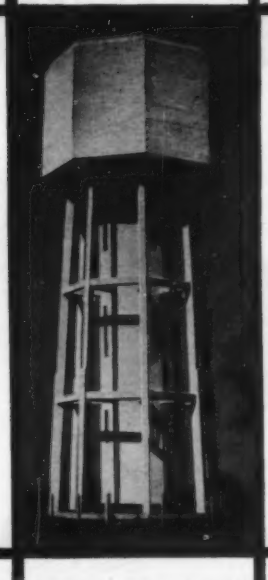

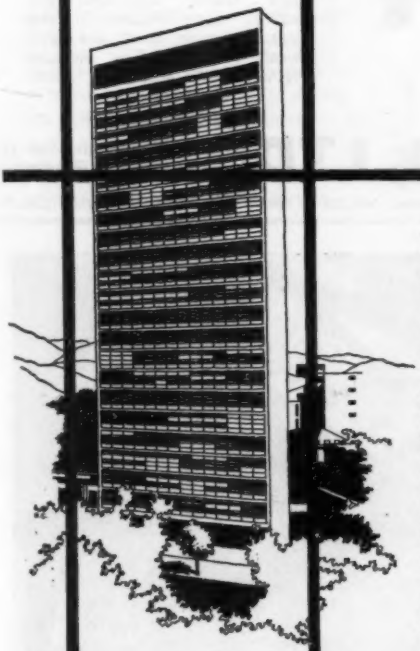

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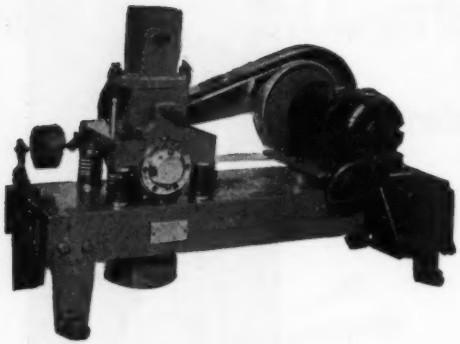

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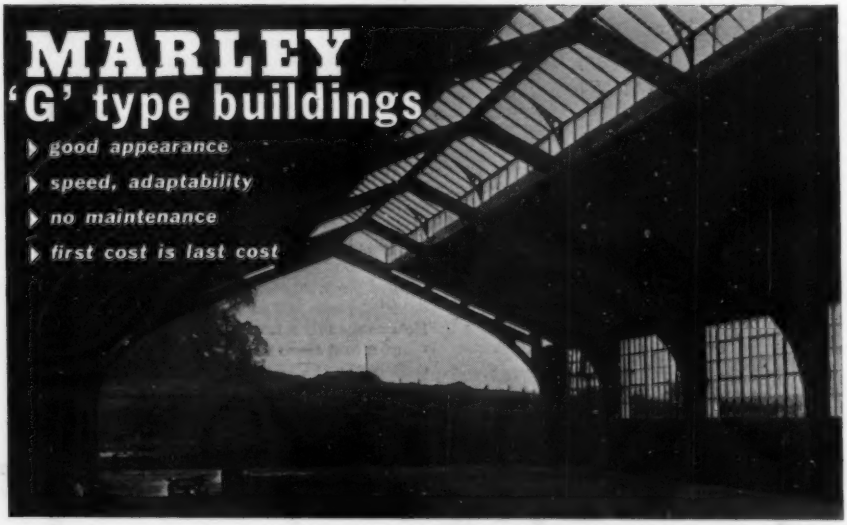

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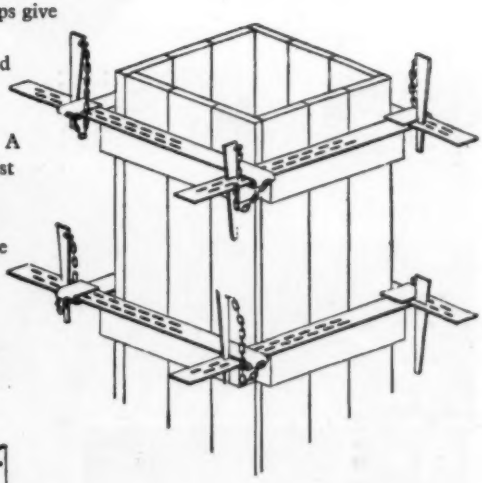

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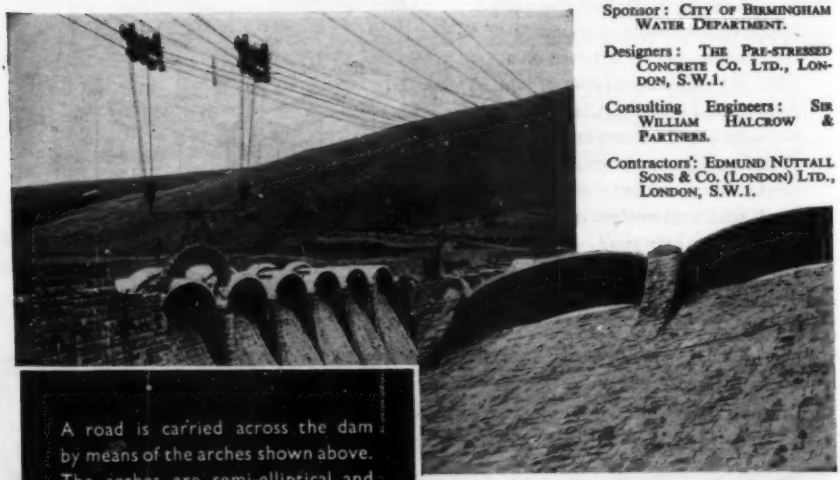

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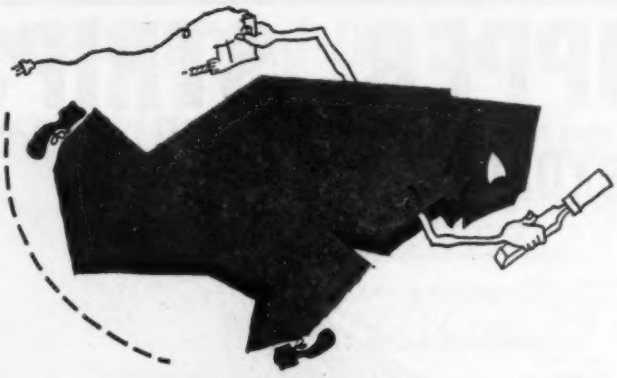

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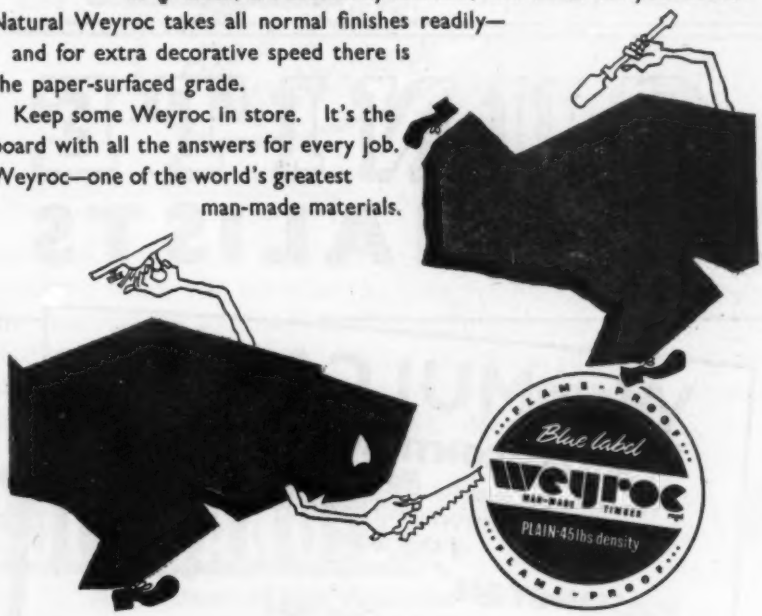

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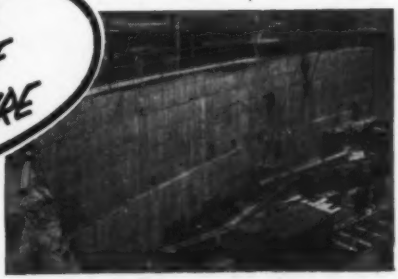

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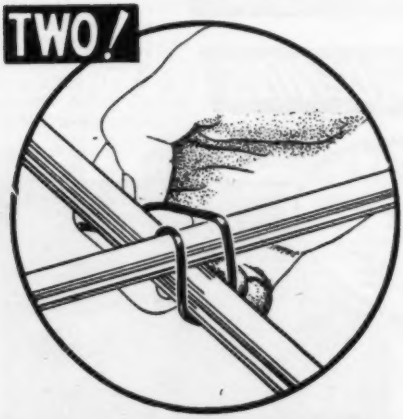

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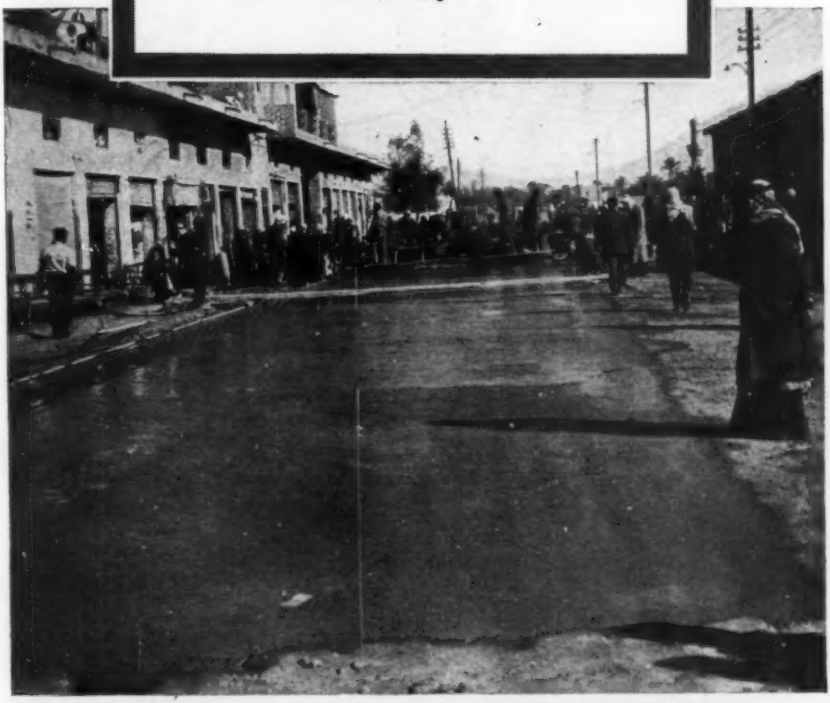

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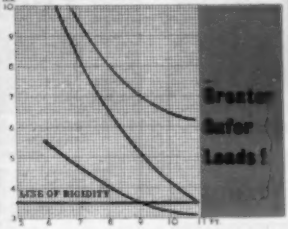

(Top curve) Ultimate Test curve for Self-Lock Prop with 5' 6" base tube and 8 swg scaffold tube inner. (Centre curve) Typical strut failure curve 3" scaffold tube with base and head plates. (Bottom curve) Safe Load curve for Mills Self-Lock Prop

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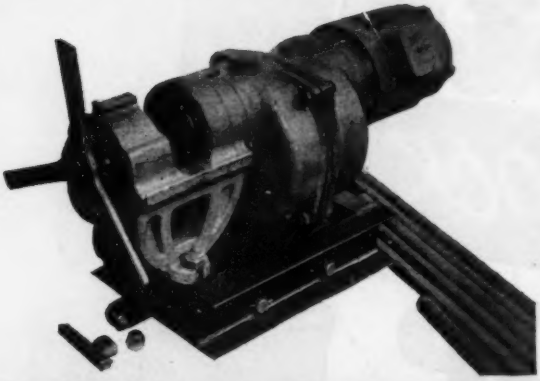

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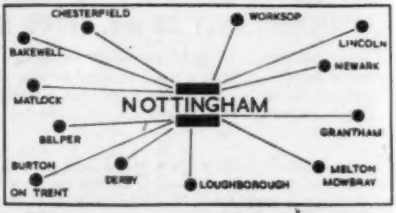

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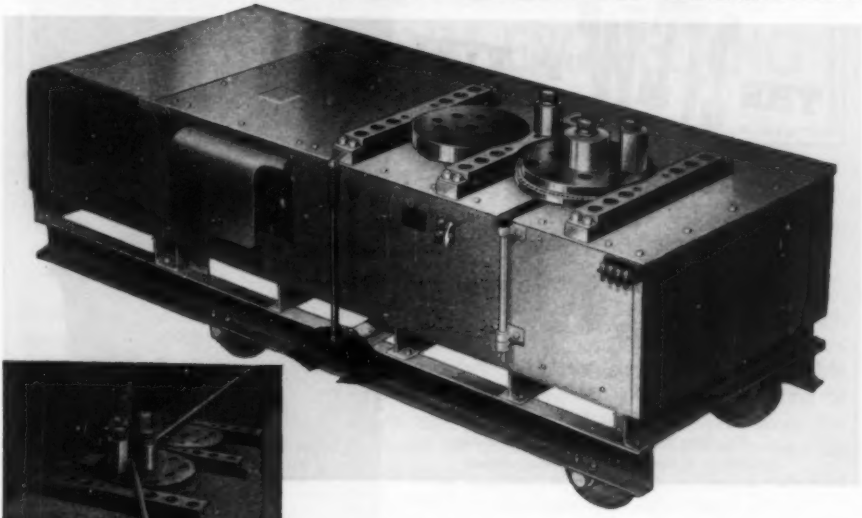

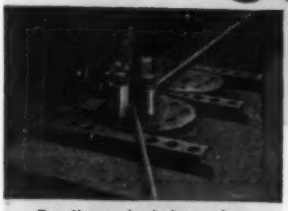

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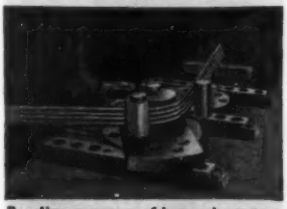

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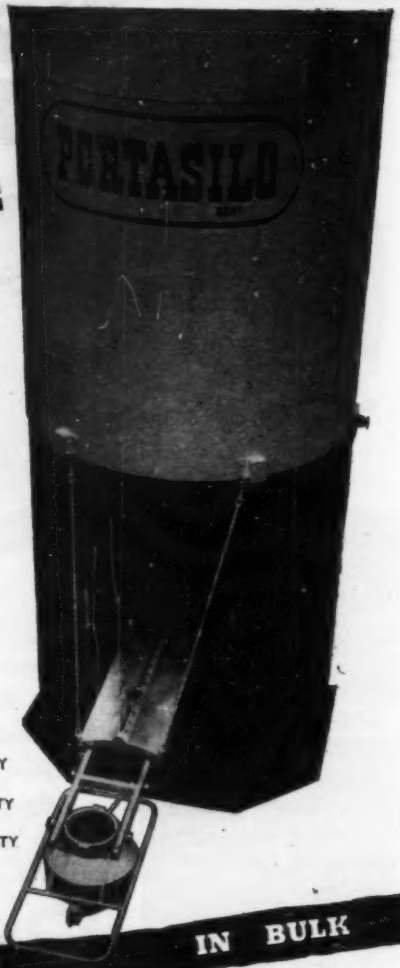

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Volume LII, No. 6. LONDON, JUNE, 1957.

EDITORIAL NOTES

A New Method of Obtaining High Early Strength.

INCREASING demands have been made in recent years for concrete with a high compressive strength at an early age. As was stated in this journal some years ago these requirements have in some measure been influenced by the allowable stresses being specified by codes of practice and regulations as a proportion of the compressive strength at a certain age, generally 28 days, irrespective of the age of the member when the loads will be applied. In this respect it may be mentioned that the draft revisions of British Standard Code of Practice No. 114 include provision for the allowable working stresses to be increased by up to 24 per cent., compared with stresses based on the crushing strength at 28 days, when it is known that the full working loads will not be applied until the member is a year old. A similar allowance was suggested in these Notes in December, 1952, and subsequently received the support of some eminent engineers both in this and other countries. Nevertheless there are times when it is desirable to have a high crushing strength as early as possible.

There are three common methods of obtaining high early strength, namely, the use of cement more finely-ground than is usual, special curing methods, and admixtures. These three methods achieve their object by increasing the rate of chemical reaction of the cement. Generally they increase shrinkage during hardening and thus the possibility of the concrete cracking. Also special curing methods frequently require the use of heat which it is often impracticable to provide on a building site; and it has not yet been proved that calcium chloride, the admixture most commonly used for hastening the hardening of concrete, may not have a deleterious effect on steel reinforcement. A new admixture recently tested in France is reported * to have increased the compressive strengths of cement mortars by 15 per cent. to 20 per cent. at an age of seven days without the disadvantages often associated with chemical accelerators.

The admixture may be one of several cementitious materials which has been hydrated, allowed to harden, and then reground. The resulting powder is added to the mixture in the proportion of about 2 per cent. of the weight of the cement content. For example, in one series of tests a paste made of water and

* 'Considérations nouvels sur les Adjuvants du Beton." By M. Duriez, Directeur de Recherches au Laboratoire Central des Ponts et Chaussées. "Revue des Matériaux", Paris. Fiftieth Anniversary number, 1955.

Portland blastfurnace cement was allowed to harden for 24 hours and cured for seven days in water. At the end of this period the hardened material was broken into small pieces and dried for five days. It was then ground in a ball-mill to a fineness of 80 microns (about the fineness of normal Portland cement). The crushing strength at seven days of 1 : 3 mortar made with ordinary Portland cement and sand was 4000 lb. per square inch ; with 2 per cent. of the admixture the crushing strength was 4700 lb. per square inch, an increase of 18 per cent. Increasing the proportion of the admixture to 10 per cent. of the weight of cement resulted in only a small additional increase in strength. Similar results were obtained with lime as a basis of the admixture. The increase in strength appears to be at least twice that which might be obtained by adding to the mixture the same amount of cement without previous hydration. Further tests have shown that the temperature at which the hardened paste is cured has a considerable influence on the effect of the admixture, but that increasing the amount beyond 2 per cent. of the cement content has little effect. With ordinary Portland cement the best results were obtained when the curing temperature was 110 deg. C. The optimum amount appears to be between 1 per cent. and 2 per cent. of the weight of cement. In general there would appear to be little increase in compressive strength at ages below seven days for ordinary Portland cement mortars. When 2 per cent. of the admixture was added to the mortar the increase in shrinkage was negligible ; but with larger amounts, for example, 10 per cent. of the weight of the cement, the shrinkage increased from 0·000042 to 0·000052. The rate of hardening is increased but the setting time is not reduced. Similar results have been obtained with high-alumina cement.

Tests have also been carried out on mortars to which have been added the cementitious admixture and also calcium chloride. It was found that the effects were additive, the cementitious admixture having a greater effect on the compressive strength after ten days than had the calcium chloride. In the case of a particular Portland blastfurnace cement the compressive strength at an age of two days of a plain cement-sand mortar was doubled by the addition of 2 per cent. of the cementitious admixture and was trebled by the addition of 2 per cent. of calcium chloride, but with the two admixtures together the strength at two days was quadrupled. At an age of seven days, however, the comparable proportions of the strengths were 1, 1·4, 1·5, 1·7, and at twenty-eight days these became 1, 1·2, 1·1, 1·4. It is possible, therefore, that a combination of the cementitious admixture and of calcium chloride could be of considerable assistance in obtaining high early strength without incurring any more risks than are generally accepted in using calcium chloride in the amounts commonly used.

An explanation of the effect of the proposed admixture may be sought on the basis of the crystallisation theory due to Le Chatelier. This states that the setting and hardening of cement paste is due to the precipitation of interlocking microscopic crystals in a supersaturated solution. To a large extent the solidification takes place by the formation of more crystals on those previously precipitated, that is, by the growth of more or less isolated crystals. The introduction of previously-hydrated crystals provides favourable conditions for the precipitation to take place and thus encourages the earlier formation of a solid mass. Explanations based on the colloidal theory have also been put forward.

The Use of High-tensile Steel Reinforcement.

By K. HAJNAL-KÓNYI, Dr.Eng., M.I.C.E., M.I.Struct.E.

In the Fiftieth Anniversary Number of this journal (January, 1956) several articles, particularly those from Austria, Sweden, and Switzerland, mentioned the increasing importance of high-tensile steel as reinforcement in concrete. Of nine papers on reinforced and prestressed concrete submitted to the congress of the International Association for Bridge and Structural Engineering in Lisbon and Oporto in 1956, six were concerned with this subject. It may therefore be of interest to survey the history of high-tensile steel reinforcement and to consider its influence on the design of reinforced concrete structures.

The term " high-tensile " steel is rather indefinite and can be applied to any steel which has a higher yield-point and ultimate strength than mild steel, although British Standard No. 785 includes an intermediate quality, known as " medium-tensile " steel, which has a guaranteed minimum yield-point of 16·5 to 19·5 tons (37,000 lb. to 43,700 lb.) per square inch, depending on the diameter, and an ultimate strength of 33 to 38 tons per square inch irrespective of the diameter. For high-tensile steel, B.S. No. 785 specifies the following minimum values for the yield-point.

Size of Bar	Tons per sq. in	Lb. per sq. in.
Up to and including 1 in. diameter or thickness	23	51,520
Over 1 in. up to and including 1½ in.	22	49,280
Over 1½ in. up to and including 2 in.	21	47,040

Bars of high-tensile quality with a diameter greater than 2 in. are hardly ever used as reinforcement, and bars larger than 1½ in. diameter are not commonly used.

The ultimate strength specified is 37 to 43 tons (82,900 lb. to 96,300 lb.) per square inch irrespective of the diameter. The lowest value of the yield-point for high-tensile steel, as defined in this country, is about 50,000 lb. per square inch, which is about the same as that used in other countries. The ultimate strength of the steels specified in B.S. No. 785 does not affect the design or the safety of structures. It is not so easy to determine an upper limit for the yield-point or ultimate strength. This article is concerned with ordinary reinforced concrete, and not with prestressed concrete. From the point of view of strength, a wide range of steels is available for use in both ordinary reinforced concrete and prestressed concrete. However, there is in practice a limit to the working stress which, for steel of very high strength, is lower than the limit based to considerations of safety only. An attempt will therefore be made to determine the limiting properties of the types of steel which could be used economically in ordinary reinforced concrete, that is, with the same factor of safety as is permissible for mild steel.

High-tensile steel complying with B.S. No. 785 has a high strength as a result of its chemical composition and is used without further processing in the condition in which it leaves the rolls. Another group of high-tensile steels is produced by rolling the steel while it is hot and then subjecting it to cold working by stretching or twisting, or both. The raw material may be mild steel or steel with a higher strength. By cold working the yield-point and the ultimate strength

are both raised, the former more than the latter. The yield-point is generally eliminated by cold working, the stress-strain diagram becoming a continuous curve with a slope which gradually decreases as the stress increases, but by convention there is a point on the stress-strain curve which may be considered as the equivalent of the yield-point of ordinary steel. The stress at this point is generally called the proof stress, and may be defined either as the stress corresponding to a certain total strain or as a stress corresponding to a certain permanent strain. In B.S. No. 1144 it is defined as the stress at which the strain is 1/200. (It is inaccurate and misleading that both B.S. No. 1144 and B.S. No. 1221 adopt the term " yield stress " for the proof stress.) In most Continental countries the proof stress is the stress corresponding to a permanent (inelastic) strain of 0·2 per cent. In practice there is very little difference between the two definitions. For the purpose of this paper steel which has a minimum yield-point or proof stress of about 50,000 lb. per square inch is regarded as high-tensile steel.

High-tensile steel may be used advantageously both in tension and in compression, but as the principles governing safe design in the two cases are different, the use of high-tensile steel for compressive reinforcement is considered separately.

Early Applications.

The use of high-tensile steel as reinforcement is as old as reinforced concrete itself. William Boutland Wilkinson, a plasterer of Newcastle-upon-Tyne,[1] obtained a patent in 1854 in which he described the use of flat bars or second-hand wire ropes to reinforce concrete where tension was to be expected, and indicated clearly the distribution of tension in a beam. About 1865 he built a reinforced concrete house in accordance with his patent, and this was in excellent condition when it was demolished about ninety years later. The upper floor of this house was constructed with concrete T-beams, with ribs spanning both ways, reinforced with twisted wire ropes, of $\frac{5}{16}$ in. to $\frac{3}{8}$ in. diameter, in the bottom of the ribs and inclined upwards at about 30 deg. at the ends before being anchored to the main beams or to the walls. Wilkinson may have been the inventor of reinforced concrete, as Monier, who is often mentioned as the inventor, did not obtain his first patent until 1867. Monier suggested using wire-netting reinforcement, which may also have consisted of steel of a higher strength than mild steel. In his patent he described the manufacture of large flower-pots formed of wire netting surrounded by cement mortar about $\frac{3}{8}$ in. to $1\frac{1}{2}$ in. thick; this seems to be the earliest form of the material now known as " ferro-cement ", an invention attributed to Professor P. L. Nervi. It is likely, however, that both Wilkinson and Monier used materials ready to hand, and did not take into account the possibility that the twisting of the strands of the ropes or the stretching of the wires of the mesh increased the tensile strength of the steel.

Professor Mátrai, in Hungary, used stresses of 28,450 lb. per square inch in wire ropes before 1900. Probably he was the first to take advantage of the higher strength of twisted wires as reinforcement, and to use stresses greater than those which over 50 years later were still considered in several countries to be dangerous. In France Hennebique introduced high-yield-point steel about 1892, using stresses which were 50 per cent. higher than those for mild steel (21,300 lb. as against 14,200 lb. per square inch).

In the United States of America E. L. Ransome obtained a patent for cold-twisted square bars in 1884. His aim was to improve the bond between steel and concrete and he proved by tests on slabs that such bars were more efficient than plain square bars of the same cross-sectional area. Square twisted bars became highly favoured in the United States, although apparently the stresses used were not higher than for plain bars. This came to an end in 1911 as the result of a report by Professor Duff A. Abrams,[2] who came to the conclusion that " the bond resistance of twisted square bars is inferior in characteristics to that of plain round bars of similar surface, and that these bars have little or no advantage in bond resistance within limits of slip which would be useful in structures ".*

The tendency in the United States was to try to obtain increased bond rather than increased strength for reinforcement bars. Thaddeus Hyatt, one of the early pioneers of reinforced concrete, realised in the 1870's that reinforcement must be bonded to the concrete throughout its entire length and that it was not enough to rely on end anchorages in the form of hooks. In his patent of 1878 he proposed " to use metal specially rolled for the purpose with bosses or raised portions formed upon the flat faces of the metal ". This idea was put into practice in the United States, and a variety of types of projections, formed on the surface of the bar in the finishing pass of the rolling mill, were used to produce " deformed " bars, such as Thacher, Johnson (corrugated square), corrugated round, diamond, lug (straight and twisted), cup and others. After many years of competition and research, the American Society for Testing Materials issued in 1947 Tentative Specifications for Minimum Requirements for the Deformations of Deformed Steel Bars for Concrete Reinforcement (A305–47T). In its latest form this specification is still tentative.

A special form of high-tensile steel, also invented in the nineteenth century, is expanded metal. It originates from a patent granted to John F. Golding of Chicago (in 1884) for a machine for making metal lath. Thin sheets of soft but tough steel were split at intervals along the grain of the metal, and then stretched to three times their original size, when the slits became oblong meshes of a size depending on the length of the slits. The manufacture of expanded metal in this country started about 1890.

The minimum tensile properties of the strands of expanded metal, as specified in B.S. No. 1221, are a proof stress of 50,000 lb. per square inch and an ultimate strength of 75,000 lb. per square inch, and it thus complies with the minimum requirements for high-tensile steel. Expanded metal was probably the first type of high-tensile steel used in large quantities in this country, although when first used the minimum proof stress was not guaranteed; the significance of the yield-point and proof stress was not recognised at the beginning of this century. According to a handbook on expanded metal published in 1905, it was assumed when designing that the working load (that is, the imposed load) was " one-fourth of the ultimate resistance of the floor ". Thus if D denotes the dead load and L the imposed load, the overall factor of safety was $\frac{D+4L}{D+L}$, and increased as the live load increased.

Since 1907, when the French Commission on Reinforced Concrete published

* It is hoped to comment on this in a later article.

its report, the application of high-tensile steel in most countries has been the subject of similar reports which were incorporated later in codes of practice and by-laws. In France the significance of the yield-point was realised and a working stress in tension equal to one-half of the yield stress was allowed. In Great Britain, however, the ultimate tensile strength remained the criterion of design. The Report of 1907 of the Joint Committee on Reinforced Concrete of the Royal Institute of British Architects recommended an ultimate strength of not less than 60,000 lb. per square inch and a working stress of 15,000 lb. to 17,000 lb. per square inch. It was not until the second Report of this Committee was issued in 1911 that the requirement of a yield-point of not less than 32,000 lb. per square inch was adopted; the working stress recommended was 16,000 lb. per square inch, with the proviso that "If stronger steel is used, the allowable tensile stress may be taken as one-half of the stress at the yield-point of the steel but in no case should it exceed 20,000 lb. per square inch." In contrast, the British Standard Code of 1957 allows a stress as high as 20,000 lb. per square inch in bars up to and including $\frac{3}{4}$ in. diameter, even for mild steel with no guaranteed yield stress complying with B.S. No. 785.

The Ransome bar (a square twisted bar) was introduced into this country before 1914 and has been available ever since. Electrically-welded steel wire fabric was also first made in the United States, and it was first made in this country in 1910 or 1911. The early tables for design recommended a working stress of 25,000 lb. per square inch, but this was contrary to the recommendations of the R.I.B.A. Report.

The scarcity of steel during the war of 1914–1918 compelled engineers to try to find ways of economising. Two attempts in this country are known, namely, (1) The introduction by Shelf of cold-twisted round bars, called "physically developed" bars, which were used in large quantities at working stresses varying between 20,000 lb. and 22,000 lb. per square inch,[3] and (2) Twisted bars of triangular cross section with rounded corners (nearly hexagonal in shape), mainly for use in shipbuilding.[4]

The history of the early applications of high-tensile steel would not be complete without reference to the high-tensile wire produced by Schroiff in Germany.[5] This wire had a diameter of 4·6 mm. (0·181 in.), a proof stress of about 7000 kg. per square centimetre (99,600 lb. per square inch), an ultimate strength of 9000 kg. per square centimetre (128,000 lb. per square inch), and an ultimate elongation of 5·9 per cent., and was used in Germany before 1914 in the construction of floors. In 1908 the working stress officially permitted in Berlin for wires of this type was 28,450 lb. per square inch (twice the working stress then permitted for mild steel). The minimum guaranteed proof stress was 6160 kg. per square centimetre (87,600 lb. per square inch), and the ultimate strength was between 8000 kg. and 9000 kg. per square centimetre (113,000 lb. and 128,000 lb. per square inch).

In 1919 and 1920 Professor Kleinlogel tested beams reinforced with wires produced by Schroiff, and in all cases the wires were broken at failure. As a result Kleinlogel proposed that a stress of 3000 kg. per square centimetre (42,670 lb. per square inch) should be permitted, which would have provided a factor of safety of 3, but the Deutscher Ausschuss für Eisenbeton, which was then responsible for the approval of higher stresses in reinforced concrete, refused

its consent. In 1921 Kleinlogel's suggestions would have made possible an overall saving of 16 per cent. compared with the cost of slabs reinforced with mild steel.

Development between 1918 and 1939.

The advantages of using high-tensile steel depend on the permissible stresses. If the maximum stress permitted is 20,000 lb. per square inch, there is no economic advantage in using steel with a guaranteed minimum yield-point exceeding 40,000 lb. per square inch. Germany was probably the first country to permit the use of higher stresses in steel of higher quality than mild steel. In 1925 the German Code allowed a working stress of 1500 kg. per square centimetre (21,300 lb. per square inch) in slabs only for St. 48, that is steel with an ultimate strength of 30·5 to 36·8 tons per square inch. This steel was inferior to " medium tensile " steel described in B.S. No. 785.

The development of the use of high-tensile steel in various countries is summarised in *Table* I, from which it is seen that, although " medium tensile " steel was introduced in Germany in 1925, the lead in the use of high-tensile steel came from Austria in 1928 with the introduction of Isteg steel. In the following decade new types of high-tensile steel were invented in several successor states of the old Austro-Hungarian monarchy.

This development resulted from a combination of technical and economic factors. Design and construction in reinforced concrete had reached a high standard in the old Austro-Hungarian monarchy before 1914. In 1918 steel was scarce and expensive in Austria, and there was a great incentive to use less steel but of higher strength. Conditions were more or less similar in the other successor states.

In *Table* I, where lower and upper limits are given for the yield-point and the ultimate strength, they are dependent on the diameter of the bars. For permissible stresses, the lower limit generally applies to T-beams or to concrete of low strength and the upper limit to slabs and rectangular beams or to concrete having a strength greater than the minimum required. At that time concrete with a cube strength of 225 kg. per square centimetre (3200 lb. per square inch) was considered to be of " high grade quality ".

Isteg steel consists of two bars twisted together and was invented in 1927 by Hoffman and Umlauf in Vienna. It was used in several countries before 1939 (including Czechoslovakia, Germany, and Italy), and was first made in Great Britain in 1934. On the Continent it was superseded by Torsteel and in this country by Tentor steel. An attempt to introduce Isteg steel into the United States was made in 1938, but was not very successful.

Torsteel was introduced by R. Schmidt in Vienna in 1935, and is made by twisting a round bar, rolled with two small longitudinal ribs which become helical after twisting. Roxor is a hot-rolled bar of cruciform cross section with transverse ribs.[6] Griffel steel, named after its inventor, is also hot-rolled and has a cross section designed to improve bond. It is rolled in such sizes that it can be substituted bar for bar for mild steel, using cross-sectional areas in the ratio of 2 to 3.

Sigma steel is made by twisting a round bar, and is similar to the " physically developed " bar which was used in Britain between 1914 and 1918 ; the only

TABLE I.

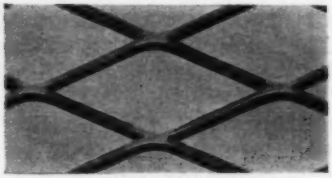
DEVELOPMENT OF THE USE OF HIGH TENSILE STEEL IN VARIOUS COUNTRIES BETWEEN THE TWO WORLD WARS

	COUNTRY	YEAR	TYPE OF STEEL	YIELD OR PROOF STRESS		ULTIMATE STRENGTH		PERMISSIBLE STRESS		METHOD OF MANUFACTURE
				KG/CM²	LB PER SQ. IN.	KG/CM²	LB PER SQ. IN.	KG/CM²	LB PER SQ. IN.	
1.	GERMANY	1932	St. 48	Not specified		4800 – 5800	68300 – 82500	1,200 (1)	21,300	H. R.
		1932	St. 52	3600 – 3600	49800 – 51200	5000 – 6400	71,100 – 91,000	1,300	21,300	H. R.
		1933	Wotanstahl-gewebe	5000	71,100	Not specified		2400 (1)(2)	34,100	C. W.
2.	AUSTRIA	1928	Isteg	3,300	49,800	Not specified		1,700	24,200	C. W.
		1935	Torstahl 52	3600	51,200	Not specified		1800 – 2000	25600 – 28450	C. W.
		1938	Torstahl 60	4000	56,900	Not specified		2000 – 2200	28450 – 31300	C. W.
3.	CZECHOSLOVAKIA	1932	Noser	3800	54,000	Not specified		1,900	27,000	H. R.
4.	POLAND	1936	Griffel	3600	51,200	5200	74,000	1,800	25,600	H. R.
5.	HUNGARY	1935	Signa	4000	56,900	Not specified		1,600 – 2000	22800 – 28450	C. W.

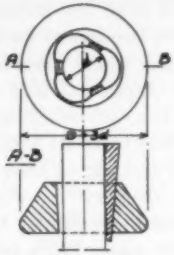
ABBREVIATIONS H. R. hot rolled
C. W. cold worked

(1) In slabs only
(2) Under special conditions the stress could be raised to 2,600 kg/cm² (37,000 lb per sq. in.)

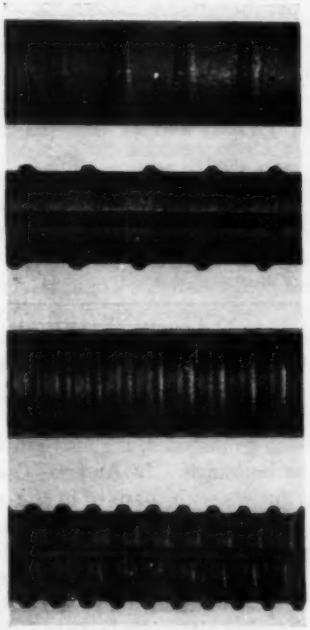
Three Types of Modern U.S. Bars.



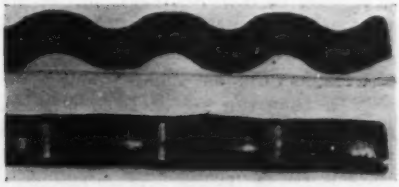
EXPANDED METAL.



FORSSELL ANCHOR.

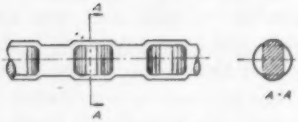


Top : KAMSTAHL 40.
Below : KAMSTAHL 60.

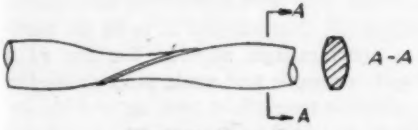


GILLBERG BAR.

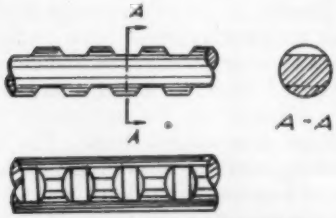
WEBRIB BAR.



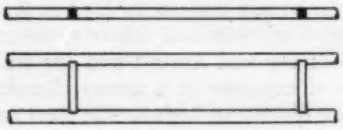
AWAKOW BAR.



TWISTED OVAL BAR.



JAKOWLEW AND GOREZKI BAR.



BI-STEEL.

GERMAN RIPPENSTAHL BAR (QUERI).

difference is that fine indentations, which are claimed to improve the bond, are made before the bar is twisted. It was used in Hungary until 1945 and is still used in Israel, where most of the reinforcement steel has to be imported. It is also popular in Argentina and Uruguay.

With the introduction in 1933 of Baustahlgewebe, for which the stress permitted was twice as high as for mild steel, Germany took the lead from Austria in allowing the use of high stresses, but after the second world war Austria was again the country in which the highest working stresses were permitted. Baustahlgewebe is similar to the welded fabric used in the United States and in this country many years before its introduction in Germany. In Germany only the proof stress is specified, which is 71,000 lb. per square inch. In this country, according to B.S. No. 1221, in conjunction with B.S. No. 785 as revised in 1952, the 0·25 per cent. proof stress must be not less than 70,000 lb. per square inch and the ultimate strength within the limits of 37 tons and 42 tons (82,900 lb. and 94,000 lb. per square inch).

In 1933 the use of Isteg steel was permitted in Germany with a working stress of 1800 kg. per square centimetre (25,600 lb. per square inch). In the following years three new types of high-tensile steel, " Ger " steel, " Nocken " steel and " Drillwulst " steel, became available in Germany. The first two were hot-rolled, and the last was both hot-rolled and cold-twisted. These steels were used at stresses between 1600 kg. and 2400 kg. per square centimetre (22,800 and 34,100 lb. per square inch), depending on their strength, the quality of the concrete, and the type of structural member. The stress allowed in T-beams was lower than in rectangular beams and slabs. After 1945 all these special steels were replaced in Germany by Torsteel.

The use of high-tensile steel, at stresses about 50 per cent. higher than those permissible for mild steel, was not restricted to buildings. In Austria, Czechoslovakia, and Germany many bridges, including girders with spans of over 100 ft., were built before 1939, using Isteg, Roxor, or St. 52, at working stresses up to 1800 kg. per square centimetre (25,600 lb. per square inch). This increasing preference for high-tensile steel occurred in Germany in spite of very strong opposition. For example, Professor Mörsch, in a paper submitted to the congress in London of the International Association for Testing Materials in 1937,[7] alleged that cold-worked steel did not offer any technical or economic advantage to the contractor or to the building owner, but only to the maker of the steel; he admitted, however, the advantage of high-tensile steel as reinforcement in columns.

A special use for high-tensile steel was in the construction of poles for high-voltage transmission lines. The German specifications allowed the use of a working stress of 40 per cent. of the ultimate strength and made practicable the use of Siemens-Martin steel, which had an ultimate strength of 7000 kg. to 8000 kg. per square centimetre (99,600 lb. to 113,800 lb. per square inch) and a yield-point of 5200 kg. to 5500 kg. per square centimetre (74,000 lb. to 78,200 lb. per square inch), at a working stress of up to 3000 kg. per square centimetre (42,700 lb. per square inch). Many thousands of poles of spun and vibrated concrete, designed using these high stresses, were erected in Germany and Austria and are still in excellent condition after up to thirty years of exposure in a severe climate.

In Great Britain the turning-point in the history of high-tensile steel came in 1933 when the Department of Scientific and Industrial Research produced the

Recommendations for a Code of Practice for the use of Reinforced Concrete in Buildings. In this document [Clause 302 (*b*)] the recommended permissible stress in steel in solid slabs, other than flat slabs, subjected to bending was 0·45 of the yield-point stress with an upper limit of 25,000 lb. per square inch up to a maximum amount of reinforcement of 1 per cent. of the effective area of slab. In this way, the early design tables for welded fabric became applicable, and the use of fabric instead of mild steel became more attractive. Although the upper limit of 20,000 lb. per square inch was retained for beams, this could be the subject of waivers by local authorities. Gradually the working stress both in slabs and beams was increased to 27,000 lb. per square inch by 1939.

In the United States high-tensile steel (known as " hard grade " steel) with a minimum yield point of 50,000 lb. per square inch and an ultimate strength of 80,000 lb. per square inch, has been in use for many years, but at working stresses of only 20,000 lb. per square inch ; there was much opposition to the use of such steel on account of its alleged brittleness.

In 1934 H. T. Gilkey and G. C. Ernst submitted a long report to the Highway Research Board on the " Use of High Elastic Limit Steel as Reinforcement of Concrete ". The authors stated that " the lower ductility of high-elastic-limit steel bars " did " not constitute a valid objection to their use ". They pointed out the need for further research with regard to welding, bond strength, deflection in bending, effects of tensile cracks, identification of grades and severe impact, and came to the conclusion that, in order to achieve economy, " advantage must be taken of the higher possible working stresses both of steel and concrete ". The following quotation from this important report of twenty-three years ago is still of interest. It characterises both the attitude of many engineers (not only in the United States) and the situation in the United States up to the present time :

> " Engineers have been slow to recognise that ductility in concrete reinforcement is useful only insofar as it enables steel to be bent and handled without fracturing it. The brittleness of the concrete itself is such that the yield-point of the steel always marks the limit of resistance of the members. Since the yield-point or elastic limit varies inversely with the ductility, it is evident that, viewed from this angle, the use of less ductile steel will, with no reduction of safety, produce stronger and more economical members. Because of a growing realization of this, there is now a pronounced trend towards increased use of higher-elastic-limit steels. Only recently intermediate-grade steel* has quite generally replaced the structural grade, and the hard grades are coming more into favour than heretofore. Up to the present time, however, the increase in working stresses allowed by most specifications has been small, and only a portion of the potential economy of high-elastic-limit steel has been realized. In other words, whatever advantages there might be have gone largely to increased factor of safety rather than to decreased construction cost."

With the exception of the U.S. Navy, which raised the working stress of hard-grade steel to 24,000 lb. per square inch during the second world war, the upper limit generally adopted in the United States is still 20,000 lb. per square inch (apart from a special case of very limited application in which it is 30,000 lb. per square inch).

* Guaranteed minimum yield point 40,000 lb. per square inch.

TABLE 2.

DEVELOPMENT OF HIGH TENSILE STEEL IN VARIOUS COUNTRIES DURING AND AFTER THE SECOND WORLD WAR

	COUNTRY	YEAR	TYPE OF STEEL	YIELD OR PROOF STRESS (1)		ULTIMATE STRENGTH		PERMISSIBLE STRESS		METHOD OF MANUFACTURE
				KG / CM²	LB PER SQ. IN.	KG / CM²	LB PER SQ. IN.	KG / CM²	LB PER SQ. IN.	
1.	AUSTRIA	1949	Torsteel "80"	6,000	85,300	y + 10 %		3,500	49,800	C. W.
		1951	Torsteel "80"	8,000	113,800	9,000	128,000	4,700 (3)	66,800	C. W.
		1954	"St" steel I	6,800	96,700	7,700	109,000	4,000	56,900	C. W.
		1954	"St" steel II	8,000	113,800	9,000	128,000	4,500	64,000	C. W.
2.	DENMARK	1946	Tentor	5,200	74,000	y + 14 %		2,200 (2)	31,300	C. W.
			Tentor	6,000	85,300	y + 14 %		2,400 (2)	34,100	C. W.
3.	GERMANY	1952	Queri	5,000	71,100	6,500 – 7,500	92,450 – 106,700	2,200 – 2,400	31,300 – 34,100	H. R.
4.	HOLLAND	1947	Torwa	4,200	59,700	5,400	76,800	2,000 – 2,100	28,450 – 29,900	C. W.
5.	ITALY	1953	Twisteel	4,800	66,800	5,500	78,200	2,400	34,100	C. W.
6.	SWEDEN	1942	Kam 40	4,000	56,900	Not specified		2,000 – 2,200 (5)	28,450 – 31,300	H. R.
		1944	Kam 60	6,000	85,300	8,200	116,600	3,300 (4)	46,900	H. R.
		1957	Glitberg	4,000	56,900	4,600	65,400	2,000 – 2,200	28,450 – 31,300	C. W.
7.	U. S. A.	1933	Webrib	4,200	60,000	Not specified		2,320	33,000 (5)	C. W.
8.	U. S. S. R.		Ani I	4,000	56,900	6,000	85,300	No data available		H. R.
			Oval Twisted	3,500	49,800	Not specified		No data available		C. W.
			Jakowlew Gorezni (6)							
			Awakow (7)							

ABBREVIATIONS H. R. hot rolled
C. W. cold worked

(1) Subject to special conditions, in Vienna only

(2) Since 1957 for structures in the absence of corrosive conditions 2,000 and 3,000 kg/cm² (32,000 and 42,700 lb per sq. in.) respectively.

(3) Code of 1949. Upper limit for bars $d = 16$ mm (0·64 in.)

(4) Used in practice but not included in code

(5) Since 1956 but only if designed by ultimate load method, otherwise 20,000

(6) Notched in one direction

(7) Notched in two directions

Development since 1939.

The scarcity of steel during the second world war favoured the use of high-tensile steel and the development of new types of bars in many countries. This development, which may not yet have ended, is summarised in *Table* II.

The most important contributions to the invention of new types of steel were made in Austria, Denmark, and Sweden. Torsteel, which originated in Austria, is now used in sixteen countries. In Austria 80 per cent. of the total steel reinforcement used is Torsteel, and the total consumption in sixteen countries was about 800,000 tons in 1955.

Another Austrian invention, " Bi "-steel (Quality I), is now made in Germany and is used at the same stresses as in Austria. It comprises two parallel cold-drawn wires connected transversely at intervals by short flat pieces. These connectors are of soft ductile steel and are welded to the high-tensile wires. The distance between the wires is 20 mm. (about 0·8 in.). The transverse pieces act as anchors over the full length and control the positions of cracks. They are 100 mm. (about 4 in.) apart for Quality I and 80 mm. (about $3\frac{5}{32}$ in.) apart for Quality II Bi-steel so as to limit to 0·2 mm. the maximum width of cracks at working stresses.

Tentor steel is a ribbed bar conforming to the American specification for deformed bars, and is cold worked by simultaneously stretching and twisting.

The manufacture of Tentor bars in this country was begun in 1951. They comply with the requirements for strength of B.S. No. 1144 and are used at working stresses of 27,000 lb. to 30,000 lb. per square inch. They are also produced in France with a guaranteed minimum proof stress of 5000 kg. per square centimetre (71,100 lb. per square inch) and a minimum ultimate strength which is 14 per cent. above the proof stress. The permissible stress in France is 2500 kg. per square centimetre (35,500 lb. per square inch). The German Queri steel, a hot-rolled deformed bar, is not at present available because of difficulties in obtaining the raw material. About 60 per cent. of the total consumption of reinforcing bars in Germany is now Torsteel.

The Dutch Torwa steel is made from a round bar which is first flattened by cold rolling and then twisted, thus forming a helical groove on both of the flattened faces. The Italian Twisteel is a twisted octagonal bar.

The Swedish Kam steel is a hot-rolled ribbed bar. The ribs of Kam 60 are closer together than in the case of Kam 40 to improve bond. Recently tests have been made on a new Kam 90 steel,[8] which is a cold-stretched deformed bar with a high carbon content having a proof stress of 9000 kg. per square centimetre (128,000 lb. per square inch) and an ultimate strength of 10,000 kg. per square centimetre (142,200 lb. per square inch) ; this has not yet been used in structures. In 1949 Professor Forssell tried to introduce a cold-stretched high-carbon plain round bar with a minimum proof stress of 8000 kg. per square centimetre (113,800 lb. per square inch) and provided with anchor-rings.[9] His aim was an increase of the working stress to 4000 to 4500 kg. per square centimetre (56,900 lb. to 64,000 lb. per square inch). Contrary to the general tendency, instead of attempting to improve the bond all along the bar, Professor Forssell used end anchors similar to those used in prestressed beams with post-tensioned steel. He is not concerned with the widths of cracks, and maintains that cracks are not more dangerous at a stress of 4000 kg. per square centimetre (56,900 lb.

per square inch) than at 1800 kg. per square centimetre (25,600 lb. per square inch). Åke Holmberg [10] has described a beam of 30 m. span (98 ft. 6 in.) with this reinforcement in which, however, the working stress was only 2300 kg. per square centimetre (32,700 lb. per square inch). The use of anchor rings would be economical only if much higher stresses were allowed in the steel. As Professor Forssell's view on cracking is not shared by many engineers it is not likely that his suggestion will be applied on a larger scale. At present about three-quarters of the total quantity of reinforcement used in Sweden is Kam steel.

The latest Swedish invention, Gillberg steel, is made in diameters up to 12 mm. (0·472 in.) only. Depressions, which are staggered on opposite sides, are made in the bar when cold, thus compressing the material. The finished product, viewed laterally, has a corrugated or zig-zag shape.

The American " Webrib " steel is a cold-twisted ribbed bar, similar in appearance to two bars twisted together but rolled in one piece in the shape of a figure eight. Information available from the U.S.S.R. is very limited and the dates of the introduction of the various new types of bars listed in *Table* II could not be ascertained. It would appear that they are all of comparatively recent origin since they are not included in the Code. The silicon manganese alloy ANL 1 is a hot-rolled deformed bar complying with the American specification for deformed bars. A new development is the manufacture of cold-notched steel.[11] Notches may be made in one or two directions at right angles. As is seen from *Table* II, the quality of the three types of cold-worked steel produced in the U.S.S.R. is so low that, according to the definition used in this paper, they hardly qualify for consideration as high-tensile steel.

Among the countries which have not developed a new type of bar of their own, but use a considerable quantity of high-tensile steel, are Switzerland and France. In Switzerland, Torsteel and square twisted bars are used ; in France, Torsteel, Tentor steel, and hot-rolled deformed bars of the American pattern.

The foregoing indicates a general tendency towards the introduction of new types of high-tensile steel and the use of higher stresses, but it reveals a great divergency of practice in various countries. In most countries high-tensile steel of adequate strength is used at stresses about 50 per cent. greater than those for mild steel, but there are the extreme cases of the United States on the one hand, where in general the upper limit is 20,000 lb. per square inch, and Austria on the other, where under certain conditions stresses up to 66,800 lb. per square inch are permitted. Both these extremes are mainly due to the economic conditions of the two countries. It is therefore necessary to examine how far these extremes are technically justified, and to determine the conditions for the use of high-tensile steel at higher stresses and the limits beyond which the working stresses must not be raised. The two main requirements to be fulfilled by any structure are safety and serviceability.

In some following articles it is hoped to discuss the theoretical and practical aspects of the applications of high-tensile steel.

(*To be continued.*)

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Research in Germany.

BOND BETWEEN PRECAST AND IN-SITU CONCRETE.—A report * by Otto Graf and Gustav Weil describes tests to determine the bond strength between precast floor beams and concrete cast in situ. Typical cross sections of the test specimens, which all had a span of 3 m. (about 10 ft.), are shown in *Fig.* 1. All the specimens were "over-reinforced" beams cast in steel moulds having smooth and oiled surfaces. In each case a satisfactory bond was observed with the concrete cast in situ four weeks later. The strength of the bond between the beams and slabs varied from 22·0 to 25·7 kg. per sq. cm. (314 to 366 lb. per square inch); the higher strength applied to beams with recesses in the webs. The committee could not agree upon a formula to assess the shearing stress along section a—a. The maximum load carried by the beams varied from 9720 to 18,750 kg. (21,400 lb. to 41,400 lb.).

LIGHT STEEL BEAMS IN FLOORS.—The second part deals with the strength of shallow light-weight steel beams used in the construction of hollow tile floors, objections to which are sometimes made on the grounds that they are not sufficiently rigid and that an effective cover of concrete is not always obtained. The authors carried out tests on the bond strength with six different types of beams made in Germany.

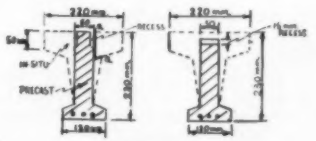

Fig. 1.

In the case of a beam with a span of 5 m. (about 16 ft. 6 in.) carrying four equally-spaced loads, the maximum load carried by the beams varied from 650 to 1000 kg. (1435 to 2200 lb.), which included the weight of the hollow tile fillers but not in every case the weight of the concrete rib or any additional load. The breaking strength of the beams was determined by the buckling resistance of the compression flange, which tended to fail sideways. The lateral stiffness of the beam was increased by the concrete rib, resulting in a greater load-bearing capacity. The factors of safety of the beams under the various conditions considered varied from 0·92 to 2·14. The paper includes diagrams and photographs of the selected beam "systems", together with complete test results in tabular form.

* "Decken aus Fertigbauteilen Versuche über den Verbund zwischen Stahlbeton-Fertigbalken und Ortbeton." "Versuche mit Stahleichtträgern für Massivdecken" (Berlin: Wilhelm Ernst & Sohn. 1955. Price 10.40 D.M.).

The Terminology of Prestressed Concrete.

DR. PAUL W. ABELES writes as follows.

I have read the Editorial Note in your May number with interest, and fully agree with you that the expressions " pre-tensioned " and " post-tensioned " concrete are grossly misleading and should be avoided. I might mention that I was responsible for introducing the expressions " pre-stretched " steel and " post-stretched " steel, which I later altered to " pre-tensioned " steel and " post-tensioned " steel. These expressions ought not to be used in connection with concrete, for which the correct description would be rather lengthy and would be as follows: " prestressed concrete with pre-tensioned or post-tensioned steel ". This wordiness may have been the cause why the simplified but misleading expressions gradually gained ground.

You state rightly that " Contractions are useful devices, but if the only contraction that can be found conveys an entirely wrong meaning it is necessary to do without it if we wish to talk and write sensibly ". In the writer's opinion such abbreviations are extremely important for practical use, but if they seem devoid of meaning it is important to create new and more suitable expressions. The writer would therefore suggest that " pre-bonded ", " post-bonded ", and " non-bonded " prestressed concrete be used. The words " pre-bonded " and " post-bonded " should indicate whether the bond between the tensioned steel and the concrete or grout is obtained before or after the concrete is prestressed. Consequently, pre-bonded prestressed concrete would relate to the pre-tensioning process and post-bonded and non-bonded prestressed concrete would relate to the post-tensioning process. The terms " pre-tensioning " and " post-tensioning " would relate only to the steel.

The writer cannot agree that the expression " pre-compressed " concrete would be better than " prestressed " concrete. On the contrary, it would narrow the subject matter. For example, in the method of prestressing a continuous beam by jacking up or anchoring down a support the construction is prestressed without direct compression being applied to the entire structure. In fact, the basic definition of prestressing (according to which stresses are induced into a structure to counteract those due to load) would be upset if the word " precompressed " were used instead of " prestressed ". Further, in the writer's opinion, it would be obscure to use the words " tension " and " compression " alone for stress, since these words may mean either stresses or forces; but it is essential to make a clear distinction between tensile and compressive stresses on the one hand and tensile and compressive forces on the other hand.

[When Dr. Abeles writes that the length of the definitions " concrete with pre-tensioned steel " and " concrete with post-tensioned steel " may have been the cause of the introduction of the shorter but " grossly misleading " terms pre-tensioned concrete and post-tensioned concrete he very convincingly confirms our argument of the folly of striving to produce short definitions which may save negligible talking time or reading time by using five syllables instead of seven. The suggested terms " pre-bonded " and " post-bonded " might be better if we could be sure that all the grouted steel in " post-bonded " concrete is in fact properly bonded throughout its length, but at present, when it is well known that prestressing steel is not always properly bonded throughout its length, the term post-bonded would be over-optimistic and therefore misleading. " Pre-bonded prestressed concrete " and " post-bonded prestressed concrete " save two syllables only compared with " prestressed concrete with pre-tensioned (or post-tensioned) steel ". The essential difference between the processes is that the steel is tensioned either before or after the concrete has hardened. If we say " concrete with pre-tensioned steel " and " concrete with post-tensioned steel " we describe the processes exactly.

The desire to use shorthand wherever possible may arise from the engineer's use of symbols in making calculations, where they are necessary if a great deal of time is not to be wasted. In making calculations we can use as much shorthand as we wish so long as we clearly remember its meaning, but a term that saves two syllables out of nine does not deserve to be called a contraction.—Editor.]

The Responsibility for British Standards.

MR. L. B. ESCRITT, A.M.I.C.E., consulting engineer, of Purley, Surrey, writes as follows.

You are to be complimented on the Editorial Note in your April number, in which you most ably discuss a matter about which there has been too much complacency. I wish to state my complete agreement with what you have said, and to make some further comments.

The British Standards Institution, without question, has done very valuable work, particularly in its earlier years. But I have the feeling that more recently the Institution as an organisation has been more concerned with quantity than with quality, and many standards that it has published must be of negligible value to the purchaser or to the writer of engineering specifications.

On the matter of writing engineering specifications, at one time it could be said that reference to British Standards saved the engineer considerable time. Now the position is reversed, for it is more difficult to keep up to date one's knowledge of new standards and the latest amendments and additions than to specify in detail one's requirements of materials and workmanship.

I think it is no exaggeration to say that more often than not engineers specify British Standards the details of which they do not know. Time and time again I have read specifications which quoted obsolete British Standards: in one instance a specification which had been withdrawn, replaced by another, and its number used for a new purpose, was quoted. Furthermore, many engineers, to save themselves trouble, have included in their specifications a clause to the effect that any material or product for which a British Standard exists shall be in accordance with that standard, thereby specifying not only standards that they have not read but also those of which they do not know the existence.

A matter which is of more importance to the public is that the high reputation initially earned by the Institution has made the B.S.I. Kite Mark of sales value. We can thus arrive at the absurd position in which Standards are prepared in such a manner as to cover the individual products of two or three firms only, the goods made by the first firm coming in Class A, those by the second in Class B, and by the third in Class C. There are also more distasteful matters of which I will say no more than that, with things as they are, little can be done to prevent them.

I would suggest that in the interests of consumers of engineering products the following changes should be made.

(1) The British Standards Institution should become a Government department entirely free from industrial control.

(2) Committees should be so formed that the professional institutions and other consumer bodies should have at least equal representation as the manufacturers and, further, that a quorum should not be considered to exist at any meeting at which manufacturers were in the majority.

(3) Rules should be laid down to prevent the preparation or continuance of circulation of standards of any products the use of which could be contrary to law, Statutory Rules and Orders, or by-laws.

(4) The Institution should endeavour to reduce the number of its publications by combining specifications which differ in detail only, and generally to improve the quality of wording and accuracy of proof reading.

[In a letter published in the April number of this journal the British Standards Institution stated that " B.S.I. is only the servant of informed industry, which uses the Institution's machinery to prepare the standards it requires ". This was written by the Institution in order to dissociate itself from a new British Standard which we had criticised in our February number, and which we later stated was so poor in quality that no responsible publisher would have issued it. We pointed out that in the foreword to this and other British Standards it is stated that they are " published under the authority of the General Council " of the Institution.

Our attention has now been drawn to a slogan used by the Institution on its postal franking machine, which states that the use of the monogram of the Institution means that the article on which it appears is " B.S.I. approved: fit for the job ".

If this does not mean that the Institution approves and accepts responsibility for the quality of products made in accordance with these British Standards, what does it mean? It is of national importance that buyers should know whether British Standards are in fact approved by the Institution and whether the quality of products that comply with the requirements of these Standards are in any way controlled by the Institution, or whether the Institution is merely an organisation for publishing standards prepared by manufacturers. The Institution seems to be at the same time claiming credit for the standards it issues and repudiating any responsibility for them. It would be useful if the Institution would let the public know which of its contradictory statements is the truth.—Editor.]

Reinforced Concrete Assembly Fixtures.

In this journal for March, 1957, it was reported that reinforced concrete frames were being used in the United States to support assembly jigs for the construction of aircraft. The Trussed Concrete Steel Co., Ltd., have now sent us details of the use of similar structures in the year 1943 in the construction of flying-boats by Short Brothers & Harland, Ltd., at Belfast. Separate fixtures were required for each of the four sections forming the hull but, as far as possible, a standard design was used for the members throughout.

Reinforced concrete precast members, pin-jointed at the bottom to castings fixed to the floor and lap-jointed at the top, formed frames which were connected by longitudinal ties at the top and at places where a change of profile occurred. The clearance between the inner faces of the frames and the component was about 2 ft. Cross-braces were provided at the top as shown in *Fig.* 1, and the end frames were rigidly supported by reinforced concrete buttresses. The largest jigs were 25 ft. in height.

Only three moulds were used for the members. Reductions in the width and height of the members to suit the shape of the hull were made by blocking off parts of the mould.

Steel fittings were placed in the mould

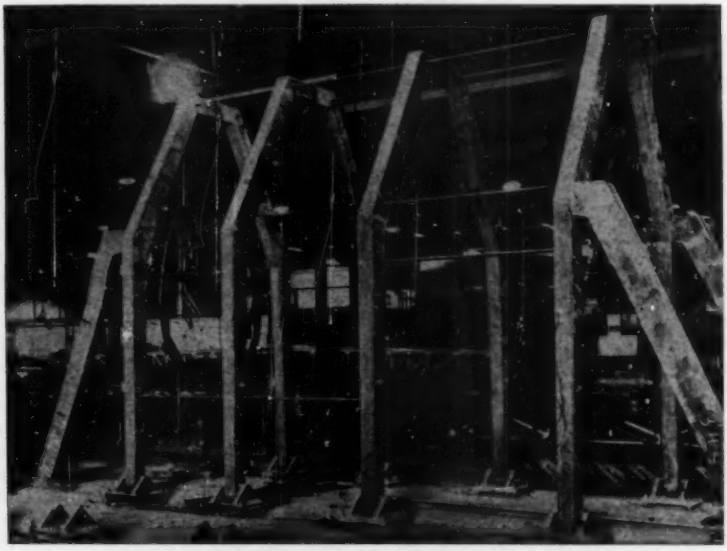

Fig. 1.—Reinforced Concrete Frame for Assembly Jigs in Aircraft Manufacture.

before the concrete was placed. In most cases the fitting consisted of two plates with holes connected by tubes welded to the back of the plates. The plates were flush with the surface on each side, and bolts were passed through the tubes to secure attachments to the frames. Wherever possible the holes were much larger than the bolts to allow for adjustment. The sockets for the top and bottom pin-joints were tubes with flanged ends. The lower tubes were bored to fit the pins attaching the bottoms of the members to the base-castings, and the upper tubes had slightly tapered holes to receive screwed cones which were used to enable them to bend if the sockets of the lap joint at the top were not in line with those in the pin-joints at the base. Tubes of 1-in. bore were also cast into the frames to receive the attachments for the longitudinal struts, and pairs of tubes were inserted about 18 in. apart to which scaffolding could be attached.

The moulds were made of steel channels and had interchangeable resin-bonded plywood bases, each drilled to suit the positions of the fittings. Metal cores were inserted through the fittings and attached to these bases, and also to wooden battens across the top of the moulds. This arrangement secured the fittings in place while the concrete was placed and vibrated. The bases could be moved longitudinally and laterally on the plates to give the required dimensions, and adjusted vertically by the nuts above and below to permit the pins to be set level. The boltheads were then welded to the base-plates and the foundations filled with concrete. The longitudinal bracing was made of tubes with flattened ends, bolted into fork-ends, which were screwed on to studs passing through the concrete members and locked with a nut and washer on either side.

The reinforced concrete members were made and erected by the Trussed Concrete Steel Co., Ltd., who also assisted in the design.

The Scientific and Philosophical Mind.

A CORRESPONDENT who writes after his name " B.Sc., Ph.D., Chartered Structural Engineer " sends the following comment : " I do not know what useful purpose your leading articles each month serve. As a designing engineer of some 27 years' practical experience, I never read them, nor do I know any of my colleagues who read them."

[Philosophy means a love of wisdom or knowledge, and a scientist is one who applies systematic and formulated knowledge to test the soundness and accuracy of conclusions. Is it not strange that a man with degrees in science and philosophy should not resolve his doubts when this can be done so easily? It would be much more in accord with the speculating and investigating mind that we associate with scientists and philosophers if our correspondent were to read one or two of these articles and form a reasoned opinion. Or have university degrees, and words, lost their meanings ?

A consulting engineer in Australia, who seems to have no degrees in either science or philosophy, recently wrote : " The receipt of your fiftieth anniversary number prompts me to write you on a matter that has occurred to me many times during the twenty years that I have been subscribing to your publication. Over the years I have derived a lot of pleasure and information from the Editorial Notes. The standard of these has been uniformly high, and they have been particularly pleasing in that a broad approach to many engineering problems has been set out in them. It is regrettable that the majority of engineers seem to be so tied up in considerations of design and construction problems that they often miss the wider and more important principles that are being formed and enforced around them. Your editorials have brought many of these principles before me, and I am grateful to you for this."

May the writer of these Editorial Notes for very many years hope that a correspondent who has read them is better able to form a sound opinion than one who has not done so ? And may he mention that a philosopher is also described as one who can be calm in trying circumstances, and is not perturbed by uncharitable comments ?—Editor.]

Liberal Education in Technical Colleges.

THE following are abstracts from a circular sent by the Ministry of Education to authorities responsible for technical training.

The purpose of this circular is to stress the importance of introducing a liberal element into technical education. The need is already widely recognised, and has been the subject of discussion and experimentation in technical colleges and elsewhere. Only so will students develop a broad outlook and a sense of spiritual and human values as well as technical accomplishment.

No one method of " liberalising " technical studies is likely to be universally possible or desirable. An advantage of full-time or " sandwich " courses over part-time courses is that the students on such courses have time to study independently and to read more widely. In part-time courses the addition of non-technical subjects will not be generally practicable unless a lead is given by the examining bodies. Nevertheless, there are other methods of liberalising a technical course which may be applicable to part-time as well as to full-time and " sandwich " courses. The liberal element depends as much on how subjects are taught as on what is taught.

The teacher of a scientific or technical subject is in the best position to inculcate habits of reflection and free enquiry which are the mark of an educated and liberal mind. All members of the teaching staff should therefore cultivate wide interests and a broad outlook. It is essential that the staff should have frequent contact with industry, and this should be apparent to the students. In some colleges, lecturers and even heads of department have been appointed to take charge of liberal studies.

It is encouraging to note that certain professional institutions are showing interest in ways in which the content of the courses for their examinations may be broadened. The employer can also help. There is reason to think that employers desire to recruit staff who, while well grounded in technical subjects, have wider interests which help them to exercise a wise control over others, and to appreciate the issues which affect the national economy. Employers are anxious to achieve more participation in the direction of technical college courses ; it is for them to ensure in co-operation with the colleges that the right type of student is produced.

The addition of extra subjects will not itself liberalise a course of technical study. Good teaching must demonstrate that these subjects have a content of fundamental interest and importance to students. Great demands will be made on the skill, ingenuity and enthusiasm of teachers who, whether technologists or humanists by training, will need to devote much fundamental thought and research to this problem. Among the additional subjects which might well be included in technical courses where time allows are human relations, English and the art of communication, economics, evolution of industry with special reference to the historical, geographical, and social development of local industries, music, art, aspects of architecture, design, literature, elements of English law, foreign languages, international affairs, political science, physical education, etc. In a full-time or " sandwich " course the time allocated to these subjects may be as much as 15 to 20 per cent. of the course. Students should learn something of the history of their science or technology and of the significance of its social and economic impacts on society. This calls for teachers who, in addition to high qualifications in their specialist fields, need to be men of broad outlook and experience.

A library is essential to a full and liberal education and to the general life of a college. The use of a library is part of the process of learning, of sifting ideas and information. There is still a tendency to keep students so closely to a time-table that most, if not all, of their time is taken up in classrooms, laboratories, and workshops. This is undesirable since the mere imparting of information may replace the active process of learning and may deprive students of opportunities of broadening their interests and outlook. Whenever possible the time-table of lectures, laboratory periods, etc., should be relaxed to enable a tutorial system to be instituted.

Large Precast Silos.

Six silos, with a total capacity of 25,000 tons of grain, have recently been constructed of precast concrete in Algeria. The granary was built in two parts. The first part (*Fig.* 1) comprises four silos, 59 ft. diameter by 120 ft. high, a workshop, a distribution tower 133 ft. high, an underground passage, a footbridge connecting the silos and the distribution tower, and some smaller structures for mechanical equipment. The second part consists of two silos 59 ft. diameter by 146 ft. high and a footbridge connecting these two silos with the main block of four silos. The following description is from an article by M. Ch. Rejcha in the French journal "La Technique Moderne-Construction" for May, 1956.

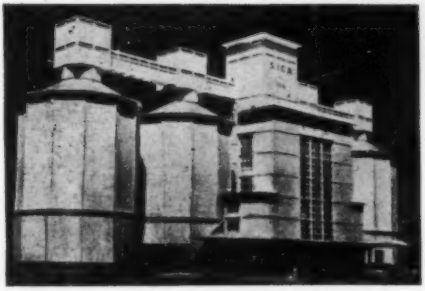

Fig. 1.

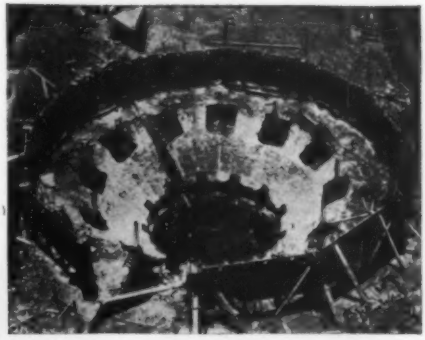

Fig. 3.—Hoppers below Ground.

The hoppers (*Fig.* 2) for the first four silos are formed of precast slabs, with joints cast in place, supported by 12-in. square columns; the hoppers for the two larger silos are below ground-level and

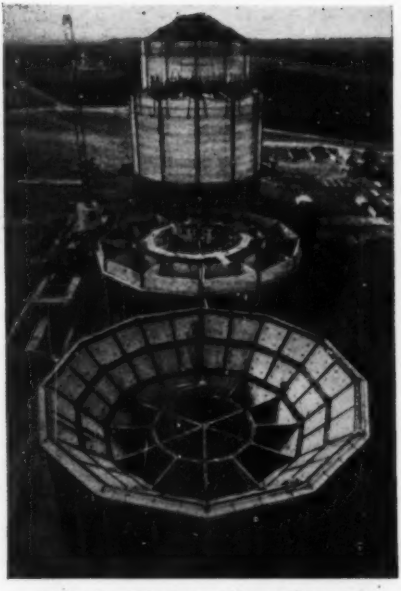

Fig. 2.—Hoppers above Ground.

Fig. 4.—Silos during Construction.

Fig. 5.—Raising a Slab from a Mould.

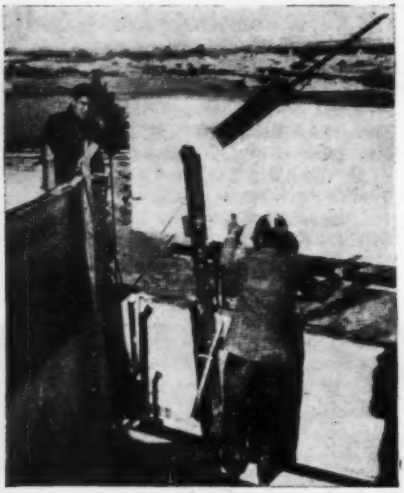

Fig. 6.—Erecting the Slab.

consist of precast slabs supported on stools, to provide an air-space, on a 4-in. slab cast on hardcore on the ground (*Fig.* 3). The upper parts of the silos are all similar, each comprising twelve trapezoidal cells forming a twelve-sided figure of 59 ft. wide from side to side, with a central polygonal compartment, 19 ft. wide, containing an elevator in a precast cylinder extending the full height of the silo (*Fig.* 4). The walls of the cells are formed of precast slabs 3 ft. 3 in. wide and varying in length from 3 ft. 6 in. to 13 ft. 3 in. and in thickness from 3½ in. to 6 in. Vertical joints between the slabs are formed of concrete cast in place around the reinforcement projecting from the ends of the slabs. The joints are also reinforced vertically to form columns. The horizontal joints between slabs are made watertight by inserting a bituminous cord of ¾-in. diameter in grooves formed in the edges of the slabs.

The slabs were cast horizontally in 50 moulds, 25 slabs being cast each day. The slabs were raised from the moulds by screwjacks (*Fig.* 5), and were transported vertically to the stacking area. The largest size of slab used was decided by the capacity of the tower crane used which was capable of carrying 1½ tons at a radius of 78 ft. Steel angles, fastened to the hoppers or to a lower slab so that they projected vertically, formed guides for the location of each slab (*Fig.* 6) and held it in position until the joints were made. The angles were then removed and refixed to the next higher slab.

At the beginning of the work the rate of progress was about 1 ft. 6 in. per day, but this was increased to 3 ft. per day as the men became proficient. The roofs of the silos were also made of precast units but the footbridge was cast in place. The granary was built for S. I. C. A. de Sainte-Barbe-du-Tlélat; the architect was M. Cantie and the contractors were the Société Algérienne des Grands Travaux de l'Est.

The Reinforced Concrete Association.

THE Reinforced Concrete Association this year celebrates its 25th anniversary and an exhibition of photographs and models is to be held, in connection with this occasion, at the Building Centre, Store Street, London, from June 18 to July 5. The exhibition, which will be opened by the Lord Mayor of London, will illustrate important structures designed and built mainly by members of the Association. There will also be exhibits dealing with the origin and work of the Association, and on the development of reinforced concrete during the past twenty-five years.

Large Prestressed Hollow Piles.

THE Lake Pontchartrain causeway in the U.S.A. comprises a monolithic prestressed precast deck, reinforced precast trestles, and prestressed precast hollow cylindrical piles of the type developed by the Raymond Concrete Pile Co.

The piles have an outside diameter of 54 in., a thickness of 4 in., and an average length of 88 ft.; 4886 of them were cast and driven.

A casting yard of 37 acres was arranged at one end of the bridge. The piles were made by spinning in steel moulds (*Fig.* 1), which were rotated at 260 revolutions per minute for an average period of ten minutes. The concrete was specified to have a minimum compressive strength of 5000 lb. per square inch at twenty-eight days.

In addition to the tensioned steel, mild steel reinforcement was used to resist stresses during transport. This comprised a cage of spirally-wound ¼-in. bars and ¾-in. longitudinal bars, which was placed in the mould together with twelve rubber tubes of 1 in. diameter extending the full length of the mould and equally spaced in the centre of the wall. After curing in steam and air, the tubes were withdrawn to leave holes for the prestressing cables.

The piles were cast in lengths of 16 ft., and these sections were laid end to end to

Fig. 2.—Tensioning the Wires.

Fig. 1.—Spinning Hollow Piles.

form the approximate length required, and the prestressing cables inserted. The cables consist of twelve steel wires of 0·192 in. diameter and with an ultimate strength of 200,000 lb. per square inch; the elastic limit was 175,000 lb. per square inch. The cables were anchored at one end by cones entering holes in a circular steel plate. Two opposite cables were tensioned at a time by hydraulic jacks (*Fig.* 2). The cables were grouted at a pressure of between 80 and 100 lb. per square inch. Much care was taken with the grouting so that there would be no loss of prestress when the piles were cut. The joints between sections were made with a thermoplastic compound, and the cable holes were enlarged at the ends of the sections so as to provide increased protection to the grout. The structure, which will cost 46,000,000 dollars, was designed by Messrs. Palmer & Baker.

A Prestressed Swimming Pool.

In *Fig.* 1 is illustrated a swimming pool recently constructed at the Club dos Caicaras in Rio de Janeiro. Built entirely of prestressed concrete, it is 75 ft. long by 41 ft. wide and has a greatest depth of 11 ft. 6 in. The following description is from an article by Sr. L. B. de Santa Maria in the Belgian journal "La Technique des Travaux" for September–October, 1956.

The pool was built on the sea-coast on ground of poor bearing capacity and where the ground-water would be harmful to concrete. The base of the pool is about 8 ft. below the level of the ground-water. A sheet-piled wall was first constructed around the site to enable it to be partially drained and fourteen piles, each about 23 ft. long, were then formed in-situ in the positions shown in *Fig.* 1. Well-points were installed to lower the ground-water farther so that the site of the pool could be excavated. The piles were formed from the higher level because of the difficulty of moving the plant for driving the lining-cylinders in and out of the excavation.

The piles support transverse beams, at about 13-ft. centres, carrying two longitudinal beams which, in conjunction with the walls, also acting as beams, form a grid supporting the 8-in. floor slab. Both the slab and the beams were prestressed, the slab being prestressed in two directions. The Freyssinet system was used and the weights of steel used per cubic foot of concrete were 1¼ lb. of mild steel and 2¾ lb. of high-tensile steel.

The design and supervision were by the Société Technique pour l'Utilisation de la Précontrainte, and the work was carried out by Estacas Franki Ltda.

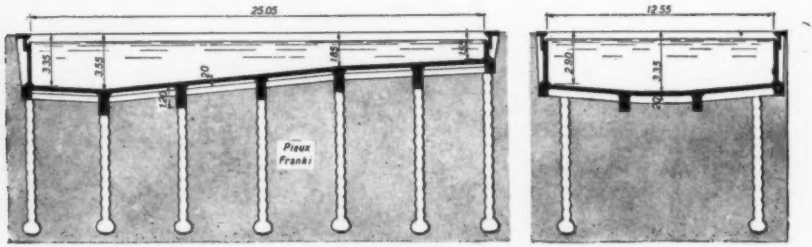

Fig. 1.—Cross Section.

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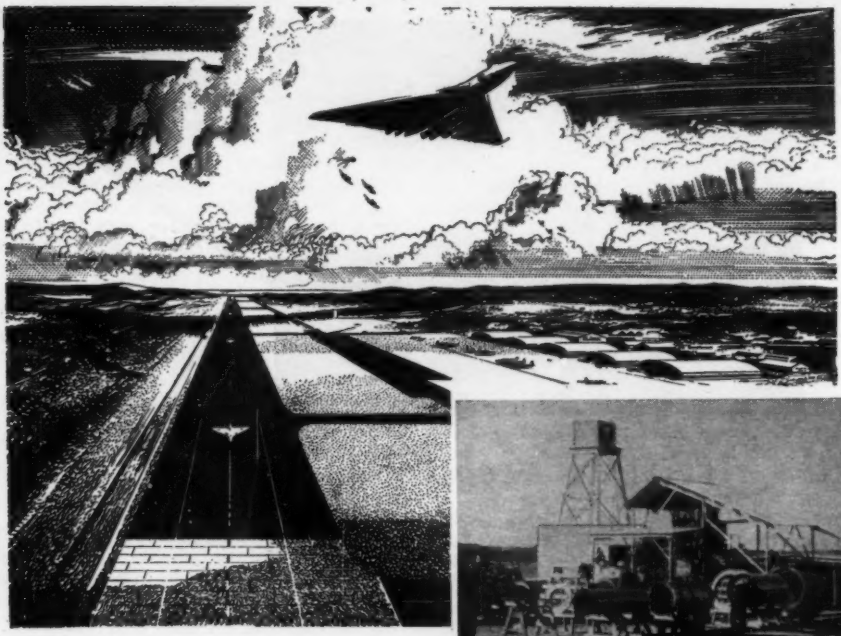

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A Church at Basildon.

THE new church of St. Basil at Basildon New Town, Essex, shown in *Fig.* 1, has accommodation for a congregation of about 400. The church is rectangular in plan, and the nave and the sanctuary are together 101 ft. long, 34 ft. wide, and 36 ft. high from the floor of the nave to the ridge. A view of the interior is shown in *Fig.* 2. The building also comprises a Lady Chapel and a baptistery forming the base of the campanile, which is 57 ft. high. The sacristies are at one end of the church behind the altar.

The structure consists of a precast frame of reinforced concrete, with brick walls and precast concrete window frames. The main frame is extended on both sides to form the aisles, as shown in *Fig.* 3. The columns are 15 ft. or 14 ft. apart. The columns of the main frame are 1 ft. 4 in. wide by 8 in. thick, and the internal columns are 36 ft. long. The columns of the bell-tower are 58 ft. 6 in. high, and are 1 ft. 4 in. wide by 1 ft. thick.

The roof is of sheet copper laid over straw-board and is lined with asbestos-wood sheets. The concrete floor includes an electric warming system, and is covered with thermoplastic tiles under the pews and concrete flags in the aisles. Fibre-glass is used at the edges of the floor slab to reduce the loss of heat.

A concrete-framed window (*Fig.* 4) of clear glass extends for the whole width of the nave at one end of the church, and there is a row of precast concrete profiled slabs below it. On each side of the main entrance are nine cruciform windows

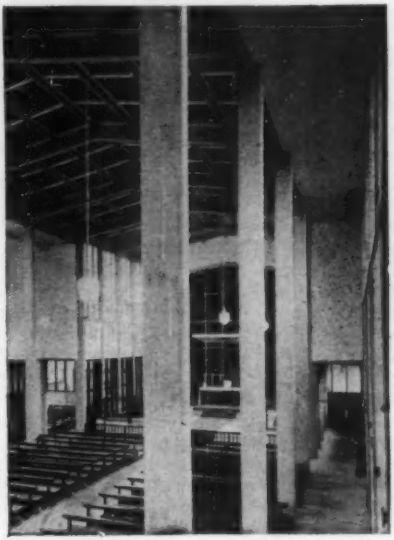


Fig. 2.—Interior.

Fig. 1.—Church at Basildon.

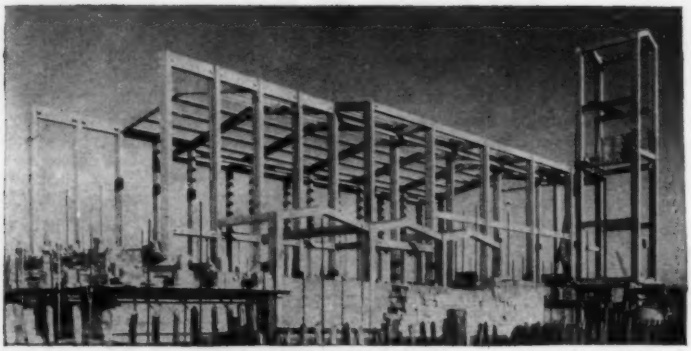


Fig. 3.—Precast Frame.

set in precast concrete frames in a brick panel faced with mortar in which coloured flints were placed by hand. There are precast concrete mullions between each row of windows. Beside the door of the side porch (*Fig.* 1) are pierced and glazed concrete panels, and there are similar panels at the base of the window on the south face of the bell-tower. The baptistery walls are of reinforced concrete tracery arranged in a chessboard pattern (*Fig.* 5), with alternate panels of semi-obscured glass and precast concrete in the form of a Maltese cross. Internally the church has white walls and a green ceiling. The trusses and purlins of the frame, which form the coffered ceiling (*Fig.* 2), are untreated, but white battens divide the longitudinal spaces between the frames into three. The west wall is deep red with white coffering.

The architects were Messrs. Burles and Newton, and the general contractors Messrs. J. Leary & Sons (Builders), Ltd. The reinforced concrete frame was designed, cast, and erected by Messrs. R. E. Eagan, Ltd. The concrete window frames and tracery were supplied by Messrs. J. A. King & Co., Ltd.

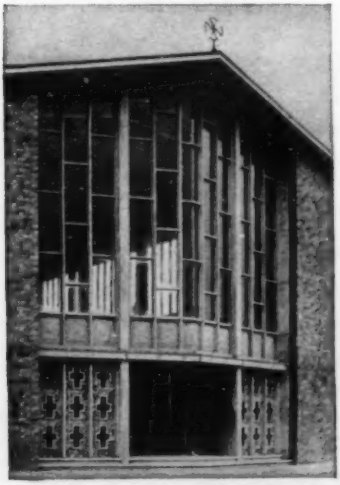


Fig. 4.—Precast Windows.

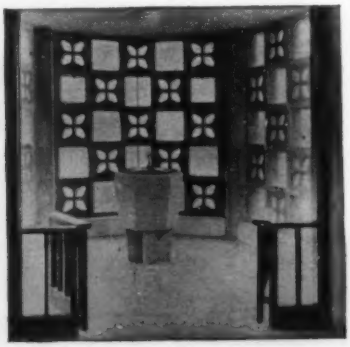
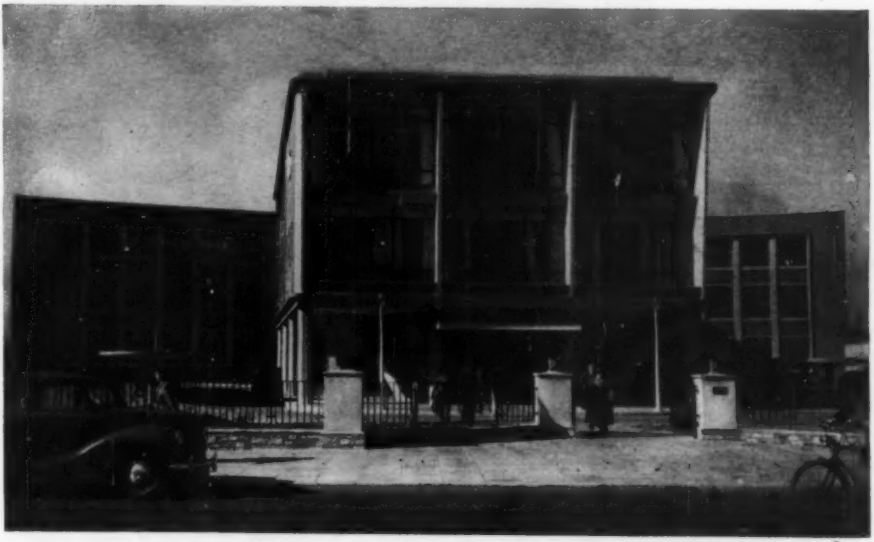


Fig. 5.—The Baptistery.



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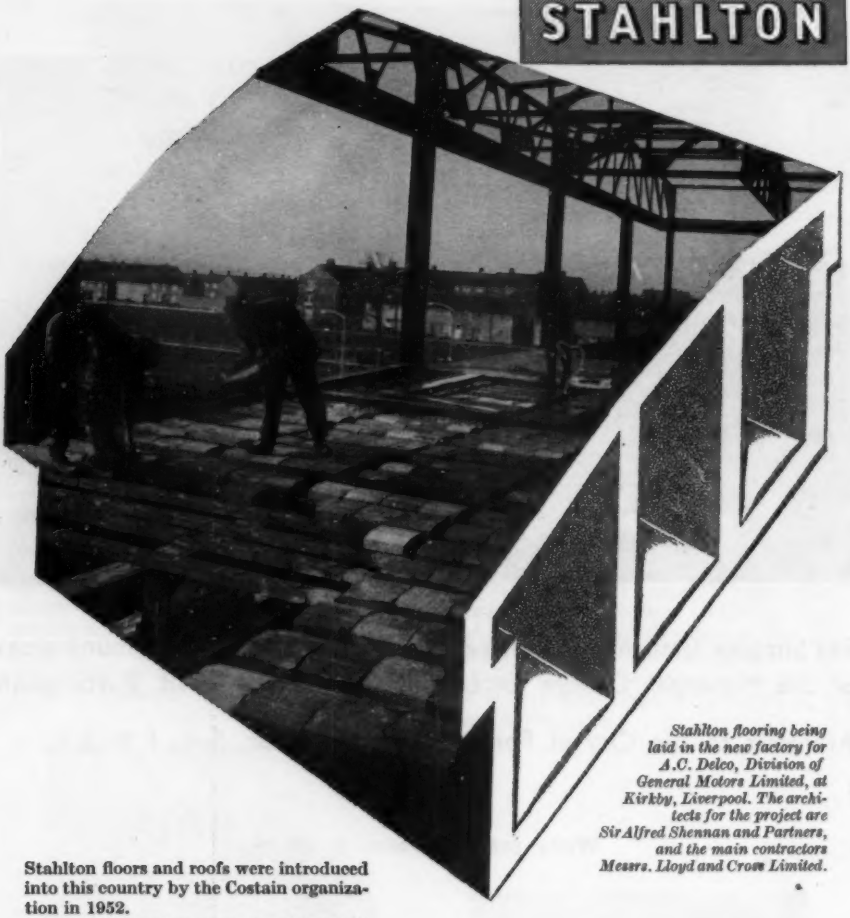

Stahlton flooring being laid in the new factory for A.C. Delco, Division of General Motors Limited, at Kirkby, Liverpool. The architects for the project are Sir Alfred Shennan and Partners, and the main contractors Messrs. Lloyd and Crow Limited.

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Dense Concrete for Shielding against Atomic Radiation.

INFORMATION on the production of dense concrete for the U.S. Atomic Energy Commission for protection against atomic radiation is given in a paper by Mr. David L. Narver in the Journal of the American Concrete Institute for January, 1956. The following is an abstract of the paper.

Limonite concrete is so named because limonite iron-ore is used as the fine aggregate. In another type of heavy-weight concrete magnetite iron-ore is used as fine aggregate. Graded scrap steel is used as a coarse aggregate in both of these types of concrete. In work completed in March, 1954, the author's firm placed at the Commission's proving ground at Eniwetok, Marshall Islands, more than 2000 cu. yd. of limonite concrete. So far, only laboratory work has been done on magnetite concrete.

The use of crushed limonite or magnetite ores as fine aggregate and graded steel scrap as coarse aggregate results in a concrete of about double the density of gravel concrete, and the shielding properties are primarily due to increased density. Such concretes are reinforced in the same way as ordinary concrete.

LIMONITE FINE AGGREGATE.—Limonite concrete has been mixed and placed by several of the usual methods. The volume of heavy material is usually controlled so that the weight of a batch is equal to the weight of a full charge of ordinary concrete; for example, a ¾-cu. yd. portable mixer could mix ½-cu. yd. batches, and 5-cu. yd. mixers could mix 2 cu. yd. of limonite concrete. Shuttering should be twice as strong as for ordinary concrete; this was effected by reducing the spacing of the studs and wales, and by increasing the size of the wales.

Such concrete has been placed successfully in walls 6 ft. thick with no serious thermal cracking. However, it was common practice to start water curing immediately after the concrete had hardened sufficiently, and to loosen the outside shuttering as soon as possible to allow additional cooling. It is believed that these practices and the reinforcement prevented cracking. The opening of joints in concrete containing steel aggregate is more serious than in other concretes. If water penetrates to the steel aggregate it increases in volume due to oxidation, and exposed steel aggregate at the surface may cause superficial cracking and spalling. The use of limonite grout at construction joints and vibration of the shutters will seal the surface and help to prevent expansion of the steel aggregate. Ordinary Portland cement was used in all the mixtures. The cooling of steel aggregate, although not practised so far, would be an advantage.

Limonite ore is a rusty-brown hydrated oxide of iron ($2Fe_2O_3.3H_2O$) with a specific gravity varying from 3·6 to 4 and, on Mohr's scale of hardness, a variation of from 5 to 5·5. The ore is crushed to the required size; however, there is a tendency for the material to break into progressively smaller sizes during crushing and a high percentage of material passing the No. 200 sieve is not desirable. To obtain the highest specific weights it is necessary to use the least possible amount of water and cement, since these are the two lightest ingredients. High percentages of fine aggregate require more water, and consequently more cement, to produce plasticity.

Of even more direct influence in the production of concrete with unit weights of 275 lb. to 310 lb. per cubic foot is the gradation of the steel coarse aggregate and the shape and surface characteristics of the particles. The specification required that cast or scrap steel particles be graded from ⅜ in. to 2 in. (A revision to this specification now under consideration restricts elongated particles by limiting the greatest dimension to twice the least dimension, and requires the rusting and consequent roughening of the surface to be promoted by removing any grease before use.) The particles were generally rounded and well rusted, both desirable features. Generally speaking, even thick rust on the surface is preferable to smooth rustless surfaces.

The ease with which this type of concrete can be made and placed depends to a large extent on the grading of the coarse aggregate. Compressive strength depends largely on the shape and surface characteristics of the particles. A workable

concrete weighing 310 lb. per cubic foot is obtainable with the following grading: 100 per cent. passing 2 in., 70 to 90 per cent. passing 1½ in., 50 to 70 per cent. passing 1 in., 30 to 50 per cent. passing ¾ in., 10 to 30 per cent. passing ½ in., and not more than 10 per cent. passing ⅜ in. The steel has a specific gravity of 7·83; the mortar of cement, limonite fine aggregate, and water has an average specific gravity of only 2·7. Therefore the weight depends on how much coarse aggregate can be incorporated.

Only two classes of limonite concrete were required, one weighing 310 lb. per cubic foot and having a compressive strength of 2500 lb. per square inch, and the other weighing 220 to 250 lb. per cubic foot with a compressive strength of 3000 lb. per square inch. If the characteristics of the available materials are known, it is not difficult to meet these requirements. For a given cement content and water-cement ratio, the compressive strength of concrete made with limonite fine aggregate and steel coarse aggregate was only slightly less than that which would be expected from some stone aggregates, such as quartz river gravel with an absorption of 0·5 per cent. or less. Such results cannot, however, be expected unless the steel coarse aggregate particles have a rusted and rough surface.

There is no direct relationship between the weight of limonite concrete and its compressive strength. Its weight depends primarily on the amount of steel in the mixture, while strength depends upon the shape and gradation of the steel and other aggregates used. Within limits, the highest compressive strengths will be produced by the denser mixtures because the amount of mixing water (the lightest ingredient) is less.

MAGNETITE FINE AGGREGATE.—Geologically, magnetite is a black iron oxide (Fe_3O_4) and is crystalline with a geologic hardness of 5·5 to 6·5 and a specific gravity of 4·9 to 5·2; 100 lb. of pure magnetite contain 72·4 lb. of pure iron. Magnetite is harder and heavier and contains more iron than limonite. The magnetite ores tested showed every indication of being as good or better than limonite as fine aggregate for heavy concrete, and had less tendency to break into smaller sizes during crushing. For a given water-cement ratio and consistency, the magnetite-ore mortar cubes indicated a compressive strength at 28 days about 8 per cent. greater than mortar cubes made with limonite ore; this is probably due in part to the fact that the magnetite ore is harder than limonite ore.

A water content of 5 to 5·5 cu. ft. per cubic yard of concrete is necessary to obtain a slump of 2 in. to 3 in. From 35 to 37 per cent. of fine aggregate was necessary to produce a workable concrete. The concrete with magnetite aggregate weighed 327 lb. per cubic foot compared with 312 lb. in the case of the densest limonite concrete. With a densely graded coarse aggregate a weight of about 330 lb. per cubic foot should be possible with a mixture of medium consistency.

Magnetite may be considered to have no water absorption. The compressive strength at 28 days of magnetite concrete is only slightly lower than that of concrete made with stone aggregate and with the same water-cement ratio of 6·2 Imperial gallons of water per cwt. of cement. This is due primarily to the use of a well-graded rusty steel coarse aggregate composed of grinding balls, ball bearings, and pieces of reinforcement bar and with a minimum of elongated pieces. The results were poor when the coarse aggregate consisted entirely of flat pieces of an unrusted hard steel alloy. Salt water was used to rust this aggregate, with alternate cycles of wetting and drying, but the compressive strength of concrete made with it was far below that of other magnetite mixtures. In general, the qualities necessary in a coarse aggregate for limonite concrete are applicable to magnetite concrete also.

There is sufficient magnetic attraction between the magnetite and the steel aggregate to make a change in the order of introduction of materials into a concrete mixer appear necessary. Several times when making laboratory tests the freshly-mixed concrete had pieces of coarse aggregate uncoated with mortar; the fine aggregate adhered magnetically to the coarse aggregate and insulated it from contact with the cement paste even after thorough mixing. A solution would be to introduce part of the cement and water into the mixer to coat the steel aggregate before the magnetite aggregate is added.

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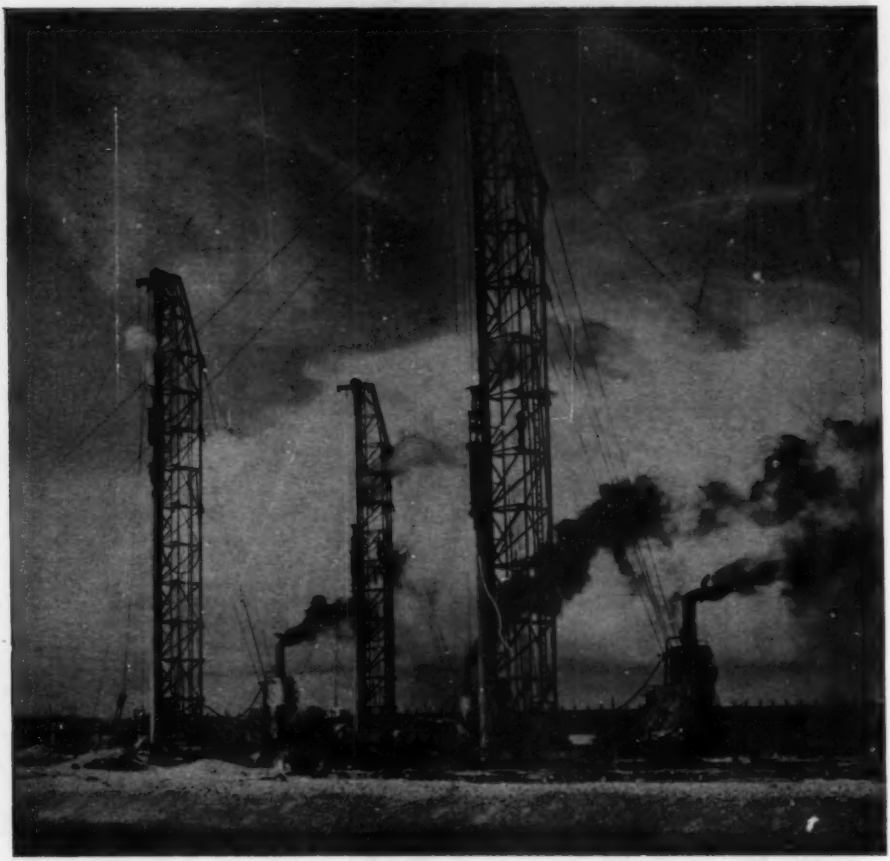

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Concrete at Atomic-energy Power Stations.

THE following notes relate to the concrete work at the Calder Hall atomic-energy power stations. There are two stations, A and B; the first was "opened" by H.M. the Queen in October last and the second will be completed this summer. The contractors are Taylor Woodrow Construction, Ltd.

The two reactor buildings at each station are 120 ft. high, and contain reinforced concrete shields as a protection against emanations from the radio-active core. Each building is founded on a reinforced concrete raft, 130 ft. by 107 ft. and 11 ft. deep; each raft contains about 5600 cu. yd. of concrete and 270 tons of steel reinforcement. The rafts were constructed in four lifts and each lift was divided into twenty-one bays. The alternate-bay method of construction was used, a period of three days being allowed between the concreting of alternate bays to allow for the shrinkage of the bays already laid.

The walls of the octagonal "biological shields" are 7 ft. thick and 90 ft. high, and further reinforced concrete walls are built around the octagonal structure. Suspended floors between the shield and the outer wall provide access and working platforms at different levels. The concrete in the shields was placed in twenty lifts, each of 4 ft. 6 in., in alternate bays to allow shrinkage to take place. The accuracy required was plus or minus one-tenth of an inch in both directions, and a complete octagonal template was first erected as a guide for the shutters, which were raised on a scaffold formed of steel angles arranged in cubes measuring 6 ft. by 6 ft. by 6 ft. The scaffold supported working platforms at various levels and the plumb-line 90 ft. long.

It was specified that the density of the concrete must not be less than 150 lb. per cubic foot, and a density of 162 lb. per cubic foot was obtained. The aggregate was Northumberland whinstone with a specific gravity of 2·9, and a detergent was added to improve workability. Compaction was by petrol-driven internal vibrators, supplemented when necessary by air-driven vibrators or by hand compaction. Steam heating and the addition of calcium chloride enabled concreting to proceed in cold weather. The shield is lined with 6-in. steel plate as a further protection.

The roof is 8 ft. thick, and was cast around a large number of charging, viewing, and other tubes. Bailey bridges were used to support the permanent steel shuttering for the roof.

The four buildings to house 23,000-kW. turbo-alternators were concreted in one lift. Men working within the shutters gave instructions by telephone to the men delivering the concrete, which was delivered through flexible tubes and compacted with vibrators. The 300 cu. yd. of concrete for each building were placed in one day.

The two cooling towers are 300 ft. high and 200 ft. diameter. They were constructed in 3-ft. lifts at a rate of one lift a day. Work was carried out from an internal steel scaffold, and as it progressed upwards the upper part of the scaffold was suspended from the wall to release the lower part for use on the second tower.

Old Trusconians

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The Volume of Construction.

INFORMATION issued by the Ministry of Works on the volume of building and civil engineering work done between January 1, 1955, and October 31, 1956, suggests that so far the "credit squeeze" has not had a serious effect on the output of the building and civil engineering industries. The totals are as follows.

First quarter 1955, £420,000,000; first quarter 1956, £473,000,000.

Second quarter 1955, £465,000,000; second quarter 1956, £533,000,000.

Third quarter 1955, £488,000,000; third quarter 1956, £533,000,000.

These totals include new houses for local authorities and private customers, new work for public authorities, private developers, and industrial concerns, repair and maintenance work, and work done by direct labour employed by Government departments, local authorities, and the nationalised industries. The repair and maintenance work done by the staffs of these public authorities increased from an average of £81,000,000 in 1955 to an average of £85,000,000 in 1956, and equalled about one-fifth of the repair and maintenance work done by contractors.

Expressed as index numbers, with 1948 = 100, the volume of work done rose from 119 in the third quarter of 1955 to 125 in the third quarter of 1956.

The number of men employed on building and civil engineering increased from 1,085,000 in October 1955 to 1,091,000 in October 1956.

Comparing October 1956 with October 1955, the number of men employed on houses decreased by 18,000; on other new work there was an increase of 45,000, and on repairs and maintenance there was a decrease of 21,000.

The index numbers of the cost of building and civil engineering work rose from 126 in the first quarter of 1955 to 130 in the second quarter, 132 in the third quarter, and 134 in the first quarter of 1956, to 136 in the second and third quarters of 1956.

Statistics are also available for the fourth quarters of the years 1955 and 1956. These show that the total value of work done was £491,000,000 in the last quarter of 1955 and £527,000,000 in the last quarter of 1956. The total work done was £1,864,000,000 in 1955 and £2,070,000,000 in 1956. The number of men employed rose from 1,043,000 in January 1956 to 1,053,000 in January 1957. The index number of cost was 133 in the fourth quarter of 1955 and 136 in the fourth quarter of 1956 (1948 = 100), and the index number of the volume of work done (1948 = 100) was 121 in the fourth quarter of 1955 and 126 in the fourth quarter of 1956.

British Exhibit of Building Equipment at the Poznan Fair.

THE largest stand in the British section of the Poznan Fair, to be held from June 9 to 23, is that of the United Construction Machinery Co., Ltd., a syndicate of ten British firms making equipment for use in construction work. The companies in the syndicate are Mackay Industrial Equipment, Ltd., Messrs. W. E. Bray & Co., Ltd., Messrs. E. P. Allam & Co., Ltd., Messrs. Ransomes, Simms & Jefferies, Ltd., Messrs. Priestman Bros., Ltd., The Marshall Fowler Group, the Liner Concrete Machinery Co., Ltd., Road Machines (Drayton), Ltd., A.C.E. Machinery, Ltd., and Messrs. Pegsons, Ltd.

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Bills of Quantities and Form of Tender will be forwarded to applicants as soon as possible after the above date, when instructions regarding the delivery of tenders will be notified.

Drawings may be inspected on site by arrangement with the Architects.

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Advertisements must reach this office by the 23rd of the month preceding publication.

SITUATIONS VACANT.

SITUATIONS VACANT. Consulting structural engineers in new modern offices conveniently situated in Central Liverpool have vacancies for reinforced concrete and structural steel designer-detailers, in the salary range of £700–£1100 per annum. Special opportunities exist for those interested in nuclear energy projects, and appointments in this field carry additional increments in salary. Positions offered are permanent with excellent prospects. Staff bonus and superannuation schemes are in operation. Apply in confidence, giving age and full details of experience, to BOX 4321, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Reinforced concrete designer-draughtsman for work in Sunbury or London office. Five-days' week. Salary £800–£1000 according to experience. Apply, stating age and details of experience, to J. H. COOMBS & PARTNERS, Consulting Engineers, Thames Corner, Sunbury-on-Thames, Middx.

SITUATIONS VACANT. R. L. BOURQUI & PARTNERS, Thermix House, Kingston-on-Thames, require detailers immediately for reinforced concrete work. Only first-class draughtsmen with good printing and linework considered. Knowledge of design an advantage, but ability to detail from calculations essential. Should be able to construct general arrangement drawings from sketches of industrial structures, framed buildings, etc. Above-average salaries offered to competent and conscientious men. Full holidays this year. Telephone for appointment to Elmbridge 0439 (office hours) or Elmbridge 2654 (evenings).

SITUATION VACANT. Civil engineering draughtsman required for work in London office of large civil engineering contractors. Work of varied nature, with scope for initiative and advancement. Commencing salary £600–£800 depending on experience. Five-days' week and luncheon vouchers. Pension scheme operates. BOX 4328, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Senior reinforced concrete engineer-designer required by a large manufacturing organisation with branches throughout the U.K. Must be conversant with Code of Practice, L.C.C. Bye-Laws, and able to design light frame structures and floor beams from estimating stage to final details. Liaison with production and sales departments of prime importance. First-class working conditions, pension scheme. Position calls for initiative and responsibility, and gives the right man a really good opportunity for progress. Salary according to experience and qualifications. Apply, giving full details and experience, etc., to BOX A. 324, CENTRAL NEWS LTD., 43 London Wall, London, E.C.2.

LONDON COUNTY COUNCIL

ARCHITECT'S DEPARTMENT

Vacancies for Engineering Assistants (up to £817) and Engineer Grade III (up to £1036) in the Structural Engineering Division.

The Division's work covers a programme of total value £12 millions this year, including multi-story flats, schools, office, warehouse and other buildings.

Particulars and application forms from the ARCHITECT (AR/EK/SE/3), The County Hall, London, S.E.1. (15.)

SITUATIONS VACANT. Assistant designer-draughtsmen with up to 3 years' experience and/or technical training required for varied and interesting work on reinforced concrete and/or steel frame structures for industrial, commercial, medical, and residential buildings. Five-days' week. Lunch vouchers. Apply, with details of experience, and salary required, to JOHN F. FARQUHARSON & PARTNERS, Chartered Structural Engineers, 34 Queen Anne Street, London, W.1.

SITUATIONS VACANT. Reinforced concrete designer-detailers required. Prospect of contemporary design experience. Salaries up to £1100 according to experience. Five-days' week. Holiday arrangements honoured. JOHN DE BREMAEKER & PARTNERS, 3 Southampton Place, London, W.C.1. Chancery 3785.

SITUATIONS VACANT. Draughtsmen and detailers experienced in reinforced concrete work required by consulting engineers in London, W.1. Junior draughtsmen also required. Five-days' week. Full details to Box 4426, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Engineer-designer required immediately by consulting engineers in London, W.1. Fully qualified and experienced in reinforced concrete and structural steelwork. Salary up to £1250 per annum. Five-days' week. Detailers and draughtsmen also required. Full details to BOX 4427, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Draughtsman (neat and rapid) required for hollow-tile flooring specialists. Design experience not essential. Applicants with good building construction or allied experience would be considered. Salary £600–£800 per annum. Five-days' week. Permanent, progressive and pensionable post. Write fully to DIESPEKER, Clifton House, Euston Road, London, N.W.1.

Opportunities for careers in Reinforced Concrete...

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There are vacancies for Reinforced Concrete Designers and Detailers at our Head Office and at most of our Design Offices in:
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Designs for a wide variety of interesting work, including prestressed and shell concrete are prepared at all offices. Five day week — Pension Scheme. Top rate salaries are paid to Designers, Designer-Detailers and Detailers in accordance with ability and experience. Openings available for graduates and men with H.N.C. Apprenticeship scheme available for students of good educational standard.

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H-W.843

THE TRUSSED CONCRETE STEEL CO. LTD.

13, Market House,
Stone Cross,
HARLOW,
ESSEX.

Telephone No. Harlow 24631.

To designers and detailers experienced in reinforced concrete.

This letter is particularly addressed to men who are interested in their work and like to work and live in pleasant conditions.

I am writing it as the Manager of my Company's office in Harlow. I have been here a year (after nine years in another of our offices) so I can speak with experience. The work itself is progressive and we try to be original; the aim of the Company has always been to give good service.

The office is new and airy and not far from where we live. Some of us bicycle or walk home for lunch. All of us in the office like our houses which we chose for ourselves from among the many types available for renting and which we were able to take over immediately before starting work. For our children there are playing fields and open country and modern schools within easy reach.

The Company's work is expanding and we are building up the staff in the office. If you are interested please drop me a line or telephone—I can arrange an interview for you here or in any of our other offices—in any case before you make a final decision we should like you and your wife to visit Harlow at our expense.

Peter Lewood M

SITUATION VACANT. Chief assistant engineer required to carry out design and supervise drawing office on work involving varying types of reinforced concrete and structural steel projects. Salary £1200 per annum, plus the usual holidays. Apply in writing, stating qualifications, etc., to ATKINSON AND PARTNERS, Consulting Civil and Structural Engineers, Elm Grove, Berkhamsted, Herts.

SITUATIONS VACANT. Reinforced concrete designer-detailers required. Familiar with L.C.C. By-Laws, and with experience of frame structures. Five-days' week, luncheon vouchers, and pension scheme. Holiday arrangements will be unaffected. Write for interview to E. J. COOK & Co. (ENGINEERS), LTD., 54 South Side, London, S.W.4.

SITUATIONS VACANT. The Glasgow office of G.K.N. REINFORCEMENTS LTD. require reinforced concrete detailers in their new drawing office. Five-days' week, pension scheme, luncheon vouchers, varied and interesting work. Write, stating age and experience, to the CHIEF ENGINEER, 30 Pinkston Road, Glasgow, C.4.

SITUATION VACANT. Diespeker & Co. Ltd. require for their drawing office at Colney Heath (St. Albans) precast concrete works, a designer-draughtsman experienced and familiar with the design and calculation of reinforced concrete structures, with particular application to a new form of precast floor construction. Permanent, pensionable, and progressive post. Write fully to DIESPEKER & CO. LTD., Clifton House, Euston Road, London, N.W.1.

SITUATION VACANT. Reinforced concrete designer for work in Victoria Street, London. Five-days' week, non-contributory pension scheme after three years' service, and progressive position. Five years' or more experience with reinforced concrete specialists preferred. Write, giving full particulars, to THE SPENCER WIRE CO. (DEVELOPMENTS) LTD., 53 Victoria Street, London, S.W.1.

SITUATION VACANT. COSTAIN CONCRETE CO. LTD., Newmains, Lanarkshire, requires a reinforced concrete designer whose duties would also entail the design of precast and prestressed concrete structures. Experience in these materials would be an advantage. Salary according to experience and ability. Superannuation scheme operative after establishment. The company's factory is situated in the geographical centre of Lanarkshire, and is rapidly expanding. Applications in the first instance should be made in writing to the PERSONNEL MANAGER at the above address.

SITUATIONS VACANT. Reinforced concrete detailers (senior) with considerable experience of industrial structures sought by TILEMAN & CO. LTD., Romney House, Tufton Street, London, S.W.1, Civil Engineers and Contractors. Excellent prospects offered to capable men in enterprising and steadily expanding firm. Starting salaries around £900 per annum. Holiday arrangements respected. Write, or telephone Abbey 1551, for an appointment.

SITUATION VACANT. Resident engineer required urgently for multi-storey reinforced concrete office blocks, Paddington area. Only men with experience need apply in writing to CLARKE, NICHOLLS & MARCEL, Consulting Engineers, 21–29 Westbourne Grove, Bayswater, London, W.2.

THE EXPANDED METAL COMPANY LTD.

Reinforced concrete designers and detailers required for permanent positions in London, West Hartlepool, Birmingham, and Manchester. Five-days' week. Staff pension scheme, etc. Apply in writing, giving brief details of experience, and salary required, to the Chief Engineer, THE EXPANDED METAL CO. LTD., 16 Caxton Street, London, S.W.1.

LONDON COUNTY COUNCIL

ARCHITECT'S DEPARTMENT

Vacancies for ENGINEERING ASSISTANTS, salary (up to £817) according to qualifications and experience.

Further particulars and application form obtainable from the Architect (AR/EK/DS/3), County Hall, London, S.E.1. (707.)

ARE YOU AMBITIOUS?

An opportunity occurs for a young experienced SALESMAN determined to obtain an EXECUTIVE position with a leading firm engaged in the manufacture and design of prestressed and precast products.

Write in confidence to the CHAIRMAN, BOX 4437, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1, giving full details of experience, technical training, qualifications, and salary required.

SITUATION VACANT. Reinforced concrete engineers require chief draughtsman for Middlesbrough office. Applicants should have several years' experience in reinforced concrete design and supervision of detailers. Five-days' week. Superannuation scheme. BOX 4438, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATIONS VACANT. Civil engineering design-draughtsmen staff required by consulting engineers for work in the Westminster area. Posts are long-term. While concrete experience is the more important, structural steel experience applies in at least one vacancy. Generally, the standard desirable is from second-year H.N.C. level or equivalent. Salary will be in relation to experience and technical education, and the posts generally would carry a range of £700 to £1150. BOX 4440, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Senior structural (steel) assistant required by consultants for work in Westminster, London. Experience in reinforced concrete work helpful but not essential. Ability to lead through schemes on design side under direction is essential. Post is a senior one with prospects and staff pension, etc. Salary of the order of £1000 to £1200, but will be considered in relation to technical education and experience. BOX 4439, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATIONS VACANT. Reinforced concrete design engineers with considerable experience of industrial structures sought by TILEMAN & CO. LTD., Romney House, Tufton Street, London, S.W.1, Civil Engineers and Contractors. Excellent prospects offered to capable men in enterprising and steadily expanding firm. Holiday arrangements respected. Write, stating experience, and salary required.

SITUATION VACANT. Assistant engineer required for structural and foundation work in London professional office. Degree and/or professional qualification desirable. Minimum of three years' drawing-office experience in reinforced concrete design and detailing. Knowledge of steelwork and site experience an advantage. Applicants should be capable of working with minimum supervision on work which is varied and which offers scope for initiative. Apply, with full particulars, stating salary required, to FARMER & DARK, Romney House, Tufton Street, London, S.W.1.

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Both lecturers will be required to teach and supervise research, and should have had specialist design and construction experience.

Salaries in the range £700 × 50—£1000; by £50—£1400 (these scales at present being under review). Initial salary and status according to qualifications and experience. Membership of F.S.S.U. and Family allowance scheme.

Applications should be sent, not later than 30 June, 1957, to PROFESSOR A. L. L. BAKER, Imperial College, London, S.W.7.

(*Continued on page lxvii.*)

NOMOGRAMS SAVE TIME AND LABOUR

The saving of time and labour that is possible by the use of nomograms is becoming increasingly realised. In a new " Concrete Series " book, the author presents 26 nomograms for use in the design of all the usual types of rectangular building frames; they are equally useful for reinforced concrete and steel construction.

The cases dealt with are frames with both columns fixed at the base, both columns hinged at the base, and both columns fixed at the base and hinged at the top. The nomograms relate to the design of such frames with eight different types of loading, namely concentrated, uniformly-distributed, and triangular loads on the beam ; concentrated, uniformly-distributed, and triangular loads on either or both of the columns ; external loads acting on the beam or on a column. Simple, symmetrical, and antimetrical loads are dealt with. Complete formulæ are given for all the foregoing conditions.

The principal advantage of the nomograms is the speed with which indeterminate quantities are obtained by reading from the nomograms certain non-dimensional coefficients that are functions of the properties of the frame and of the nature and position of the load.

The nomograms are in a pocket at the back of the book, so that they can be laid on the drawing board when in use, and their use is demonstrated by numerical examples.

"Nomograms for the Analysis of Frames," by J. Rygol

Price 18s., by post 19s. $4 in the U.S.A. and Canada.

Published by

CONCRETE PUBLICATIONS LIMITED

14 DARTMOUTH STREET, LONDON, S.W.1

SITUATIONS VACANT. Reinforced concrete detailers with some design knowledge required for London professional office. Experience of steelwork an advantage but not essential. The work is varied and offers scope for initiative. Five-days' week. Please apply, giving full details, and salary required, to FARMER & DARK, Romney House, Tufton Street, London, S.W.1.

SITUATIONS VACANT. Senior reinforced concrete designers required. Must be experienced in the design of foundations and structures. High salaries will be paid to suitable applicants. Modern semi-detached houses to let. Grant towards removal expenses and allowance made until removal effected. Pension and insurance scheme. Apply STAFF PERSONNEL MANAGER, ASHMORE, BENSON, PEASE & Co., Stockton-on-Tees.

SITUATIONS VACANT. Consulting engineers require reinforced concrete designer-detailers for varied and interesting structures. Work will include some site supervision. High salaries will be paid to experienced men. Five-days' week, good conditions. Applications in strict confidence, stating full details of experience, and salary required, to ALAN MARSHALL & PARTNERS, 73-74 High Holborn, London, W.C.1.

SITUATIONS VACANT. Consulting engineers require reinforced concrete designer-detailers for varied and interesting structures. Work will include site supervision. High salaries will be paid to experienced men. Five-days' week, good conditions. Applications in strict confidence, stating full details of experience, and salary required, to ALAN MARSHALL & PARTNERS, 8 Cherry Street, Birmingham, 2.

SITUATION VACANT. Bahrain. A civil engineer age 35-40 years required for work on a deep-water pier. Applicants should have experience in heavy civil engineering contracting, particularly dock construction and concrete works. Qualifications: A.M.I.C.E. or equivalent. Salary from £2400 per annum sterling, free of tax. Free accommodation and use of company's transport. Contract three years in the first instance with one month's leave per year with passage to U.K. (also for wife if married), and two months' U.K. leave at end of third year. Apply to J. C. GAMMON (ENGLAND) LTD., Burwood House, 16 Caxton Street, London, S.W.1.

SITUATION VACANT. Senior reinforced concrete designer required, preferably with specialist experience in the design of all types of reinforced concrete structures. A good salary will be paid in accordance with experience. A bonus scheme and non-contributory pension scheme are in operation. A five-days' week. Offices are adjacent to Victoria Station. Apply THE INDENTED BAR & CONCRETE ENGINEERING Co. LTD., Reinforced Concrete Engineers, 171 Victoria Street, London, S.W.1. Telephone: Victoria 1642.

SITUATION VACANT. Civil design engineer required for the staff of a large company in the North-East Coast area for design work in connection with development schemes in progress and planned. Must possess a sound, all-round experience of civil engineering as applied to industrial projects. Reinforced concrete experience is essential, and applicants should be capable of developing schemes and supervising their subsequent detailing and progress. An excellent contributory superannuation scheme is in operation, and removal expenses would be paid. Apply, stating age, experience, when at liberty and salary required, to BOX 4441, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

CENTRAL ELECTRICITY AUTHORITY HEADQUARTERS

Applications are invited for the appointment of CIVIL ENGINEERS at the RESEARCH LABORATORIES, LEATHERHEAD, Surrey, to carry out investigations into the properties of pulverised fuel ash concrete, the applications of such concrete to civil engineering projects, and the further use of p.f. ash. Candidates should have a degree or H.N.C. in Civil Engineering with at least two years' practical experience. Salary £320—£910 per annum according to qualifications and experience. Applications, stating age, experience and present salary, should be forwarded to D. MOFFAT, Director of Establishments, Winsley Street, London, W.1, by 21 June 1957. Quote reference C.C.E/195.

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offer interesting careers with good salaries and congenial conditions in the following grades:

1 Experienced Reinforced Concrete Designers.

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Our present volume of business and continuing expansion offer good prospects to suitable applicants. Five-days' week. Pension Scheme, etc.

Please apply in writing to

T. C. JONES & CO. LTD.

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Bute Street, Cardiff

Endorse envelope "Technical Staff"

SITUATIONS VACANT. Consulting engineers require designer-detailers for steel and reinforced concrete bridges, marine and industrial structures. Starting salary dependent on qualifications and experience. Good prospects. Apply PERSONNEL DEPARTMENT, SIR BRUCE WHITE, WOLFE BARRY & PARTNERS, 1 Lygon Place, Grosvenor Gardens, London, S.W.1. Telephone: Sloane 0431.

SITUATIONS VACANT. One senior and two junior or intermediate draughtsmen required in civil engineering department of small consultant engaged on colliery work. Experience should be largely in reinforced concrete, but a knowledge of building construction, drainage, steelwork, etc., would be an advantage. Keenness and adaptability more use than vast knowledge. Good salary. A. BICKERDYKE & Co., 4-6 Hammersmith Grove, London, W.6. Telephone: RIVerside 7452.

SITUATION VACANT. Prestressed concrete designer required for permanent and progressive position with opportunity for site experience. Five-days' week, luncheon vouchers and pension scheme. Holiday arrangements honoured. E. J. COOK & Co. (ENGINEERS) LTD., 54 South Side, Clapham Common, London, S.W.4.

ENGINEER DESIGNERS

required for London Drawing Office for work on reinforced concrete and general Civil Engineering design.

5-days' week, 9.0 to 5.30
Staff Restaurant.

Apply:

GEORGE WIMPEY & CO., LIMITED
W. F. G. Crozier, M.Sc., M.I.C.E.,
27 Hammersmith Grove, London, W.6.
(RIVerside 2000)

LONDON COUNTY COUNCIL

ARCHITECT'S DEPARTMENT

Vacancies for STRUCTURAL ENGINEERS AND BUILDING SURVEYORS for the District Surveyors' service. Starting salaries up to £817. Good prospects of career in interesting district work mainly outside. Particulars and application form, from the Architect, AR/EK/25/57, County Hall, London, S.E.1. (897.)

(Continued on page lxviii.)

DONCASTER BY-PASS MOTORWAY ENGINEERS REQUIRED

THE WEST RIDING OF YORKSHIRE COUNTY COUNCIL is to undertake, on behalf of the Ministry of Transport and Civil Aviation, the design and supervision of construction of this important By-Pass which is one of the largest motorway schemes so far programmed to be undertaken by a County Council.

In addition, other road and bridge improvement schemes of considerable magnitude are anticipated shortly.

The following appointments are to be made from candidates of any age and will offer outstanding experience in all aspects of modern bridge and highway engineering design and construction.

SENIOR BRIDGE ENGINEERS up to £1625 per annum.
ASSISTANT BRIDGE ENGINEERS up to £1230 per annum.
ASSISTANT ROAD ENGINEERS up to £1230 per annum.
JUNIOR ASSISTANT ROAD AND BRIDGE ENGINEERS A.P.T. GRADES I to IV.
ASSISTANT LABORATORY ENGINEER up to £1230 per annum.
SENIOR ASSISTANT MECHANICAL ENGINEER up to £1515 per annum.
ASSISTANT MECHANICAL ENGINEER up to £1230 per annum.

Candidates must have appropriate professional qualifications and experience as follows:—

Bridge appointments—in modern bridge design and construction.

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Mechanical appointments—in the construction, use, repair and maintenance of modern civil engineering plant and transport.

All appointments are permanent and pensionable and subject to normal County Council regulations governing conditions of service, subsistence and travelling allowances.

Application forms and further particulars from the COUNTY ENGINEER AND SURVEYOR, County Hall, Wakefield. Completed forms to be returned by 24th June, 1957.

SITUATION VACANT. An excellent opportunity has arisen for a design-detailer to join well-known prestressed and precast concrete manufacturers in their London office. At first the successful applicant will work with the company's consultant in prestressed concrete design, but after a short period will be left to supervise and expand his own section. Write, stating age, experience, etc., to Box 4443, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Technical director required to be in charge of building materials' testing and research laboratories. The position offers good salary, participation in pension scheme, and housing accommodation. Please send applications, outlining previous experience, salary required, etc., which will be treated in confidence, to BOX 4444, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION WANTED.

SITUATION WANTED. Civil engineer (B.Sc., A.M.I.Struct.E.), with 6½ years' experience in reinforced concrete design and construction for internationally-known firms. Prepared to travel. Write "ENGINEER", c/o Box 4671, Johannesburg, South Africa.

SERVICES OFFERED.

SERVICES OFFERED. Experienced engineer offers free-lance services to the profession in the design and detailing of steel, reinforced concrete, and civil engineering work. BOX 4435, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SERVICES OFFERED. Statistician and mathematician, with experience of constructional engineering problems, available for consultation. Telephone GRE (London) 3491, or write to Box 4442, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

FOR SALE.

FOR SALE. Refuse containers repaired and modified. General metalwork, all types. E. STEPHENS & SON, LTD., Bath Street, London, E.C.1. Clerkenwell 1731.

FOR HIRE.

FOR HIRE. Lattice steel erection masts (light and heavy), 30 ft. to 150 ft. high, for immediate hire. BELLMAN'S, 21 Hobart House, Grosvenor Place, London, S.W.1.

FOR HIRE. Travelling tower crane for immediate hire, Model G.12, complete with tracks and turntables. Keen rates. PLANT DIVISION, C.I. LTD., Staffa Road, Leyton, E.10. Telephone: Leyton 3678.

CONCRETE FENCES

A recent book, entitled "Concrete Fences", by A. M. Pennington, a products manufacturer of many years' experience, describes in detail the design and the most suitable methods of manufacture and of erection of all the usual (and some uncommon) types of concrete fences for all purposes. Many hints based on experience.

The chapters deal with (1) Proportions of concrete; moulds; reinforcement; inserts for fixtures. (2) Estimating quantities. (3) Erecting fences. (4) Types of fences—Three-wire; seven-wire; chain-link; woven-wire; barbed-wire; post-and-tube; post-and-bar; post-and-panel; post-and-block; close-boarded; race-course fences; chain-fences; ornamental fences; "crash" fences; stub posts; gravel boards. (5) Design of posts.

64 pages. 60 illustrations.

Price 6s. (by post 6s. 4d.)
1.50 dollars in Canada and U.S.A.

CONCRETE PUBLICATIONS LTD.
14 DARTMOUTH STREET, LONDON, S.W.1.

BACK NUMBERS OF "CONCRETE and CONSTRUCTIONAL ENGINEERING"

The Publishers frequently have enquiries for back numbers of "Concrete and Constructional Engineering," generally from universities and similar institutions abroad. Readers who have copies published before 1954 (either bound or unbound) which they no longer require are invited to send a list of the dates to the Publisher, Concrete Publications, Ltd., 14 Dartmouth Street, London, S.W.1. Generally at least the published price can be offered for such back numbers.

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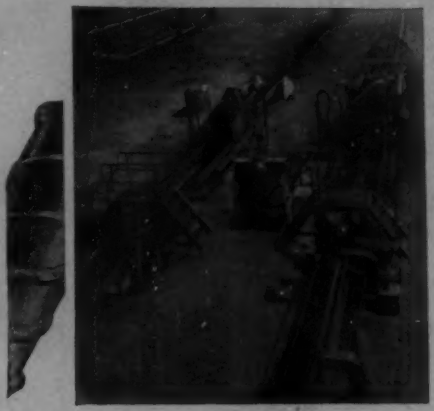
here's the plant—



We are happy to announce that, following the installation of additional plant to satisfy the increasing demand for Tentor, the factories at Cardiff and Sheffield are now able to meet delivery dates at considerably shorter notice.

Here's the saving—The machines shown here are the background to the success of the Tentor Bar. They ensure the high standards of tensile and bond strength which lead to economies of anything up to 15% of the cost of plain mild steel rounds.

Here's the service—We have always made a point of seeing to it that Tentor service is on a level with the product itself. Deliveries are made strictly to your site programme, with bars cut to length or bent to schedule as required.

Tentor is manufactured by Guest Keen & Nettlefolds (South Wales) Ltd., Cardiff; McCall & Co. (Sheffield) Ltd., Templeborough, Sheffield; The United Steel Companies Ltd., Sheffield.

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Company Limited
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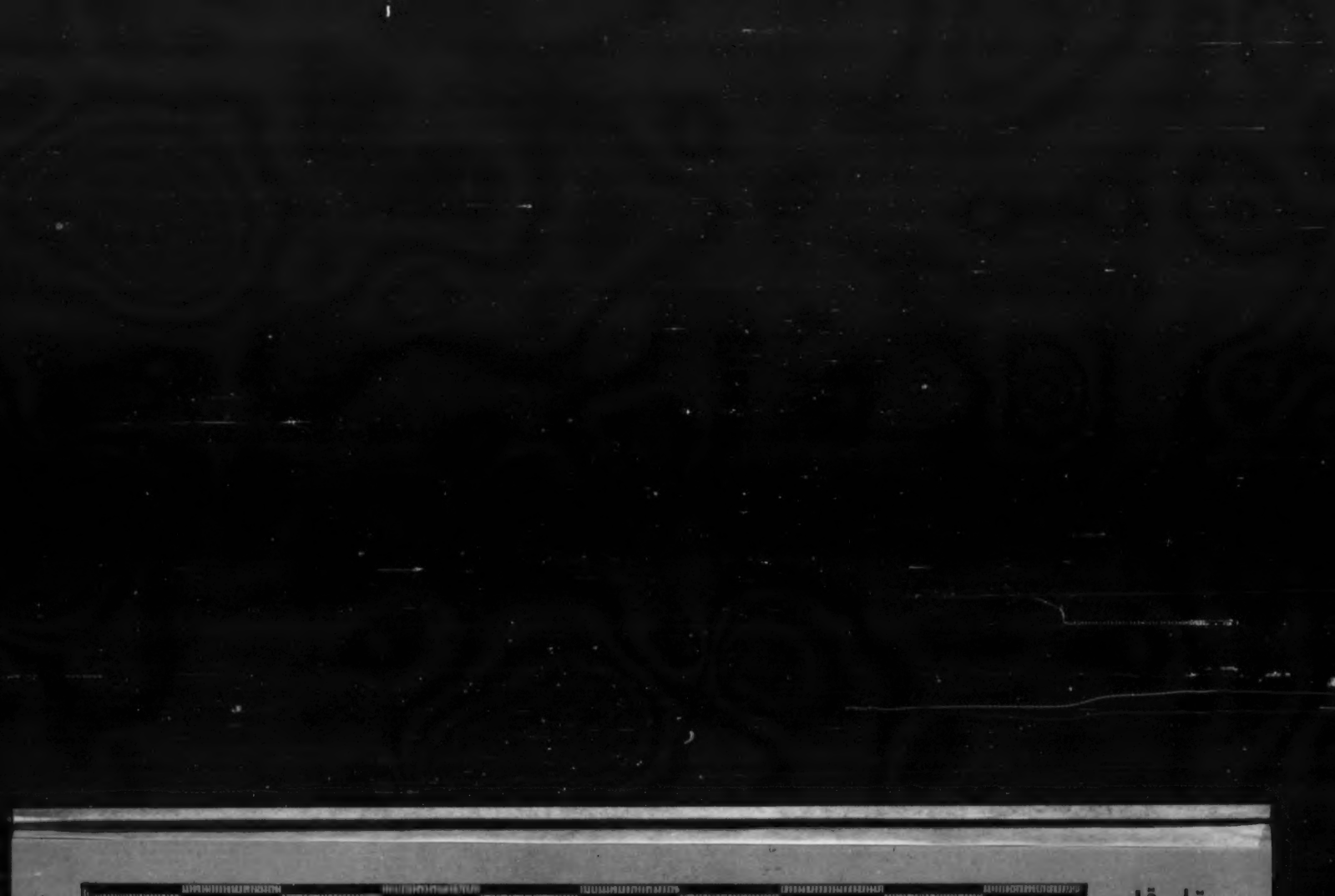
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